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The Rotation of the Galaxy

The above phrase had very little content for even the most progressive astronomers at the beginning of the present century This circumstance is doubtless a natural corollary of the fact that to them the terms *galaxy* and *universe* were interchangeable, and it did not seem necessary to ascribe motion to the entire creation. The idea of a motion in which the galaxy as a whole takes part fits better with the thought that the galaxy is only a unit in a still vaster whole.

Very early in the development of the science of astronomy the phenomenon of rotation and the phenomenon of revolution were recognized. The solar system furnishes numerous examples. The uninterrupted alternation of day and night shows quite conclusively the rotation of the earth on its axis. Evidence, not quite so direct but still convincing, shows a similar motion in most, if not all, of the other planets, as well as in the moon and in the sun. The planets, the asteroids, and the comets furnish almost countless instances of revolution about a common center, in this case the sun. From the fact that the sun is like other stars in all essential respects, reasoning by analogy would suggest that other stars are centers of similar units, each having a motion in which the whole unit is concerned. However, observational evidence of this is lacking.

When the galaxy came to be recognized as one star system among other similar systems, the imagination of man readily envisaged a motion, similar to that in the solar system, belonging to the galaxy as a whole. The recent years are bringing facts to light which substantiate this concept. The picture, because of its enormous proportions, cannot easily be made vivid. A single comparison will indicate the scale. The earth completes one rotation about its axis in one *day,* but the earth, the sun, and the stars in the neighborhood of the sun, considered as a part of the rotating galaxy, require, if early results are correct, two hundred twenty million *years* to complete one galactic rotation.

As the traveler in mountainous regions attains one summit only to see other and higher summits ahead, so the mind of man from generation to generation advances to higher and higher concepts of the material universe in an apparently unending succession.

Shadow Bands

By RICHARD L. FELDMAN

(PART II)

My first article on shadow bands appeared in the issue of POPULAR ASTRONOMY for April, 1938. Therein was set forth the first detailed summary of the hundred-odd collected reports of the phenomena as observed during the eclipse of January 24, 1925, bearing out the writer's independently-conceived hypothesis that the bands are concentric with the moon's shadow. The article included a new summary of the 33 reports made to Professor Frank H. Bigelow, U. S. Weather Bureau, on the May 28, 1900, eclipse through the Southern States; a brief examination of the 1918 data assembled by S. P. Fergusson; and extracts from the summaries of A. Lawrence Rotch, Harvard College Observatory, on several eclipses, notably that of August 30, 1905. The last part of the article described in detail the author's predictions and subsequent reports collected from responsible observers at the eclipses of June 19, 1936, and June 8, 1937. The bands reported by two out of three observers in 1936, and by three out of three observers in 1937, were in very close agreement with the predictions made on the author's hypothesis and announced in advance.

In this paper and in Part III, to follow, I shall describe the principal explanations which have come to my notice, and shall show their untenability. Further, I shall offer my own explanation which, while, of necessity, incomplete for lack of data, seems to offer a key to a phenomenon often described as "mysterious."

The critical reader is asked to keep in mind certain peculiarities of behavior of the bands which are demonstrated to exist.

1. It is only at points along the center line of the path of totality that the line of extension of the bands is the same after totality as before; an abrupt difference is always observed elsewhere, this difference approaching a right angle as the locations reporting are farther and farther out from the center line.

2. Although these abrupt changes in extension are noted between pre- and post-totality, an interval which seldom exceeds two or three minutes, nevertheless (and this is important in objecting to the "air wave" refractionists) *no abrupt changes* during the pre-totality period, or during post-totality, seem ever to have been reliably reported. On the other hand, points near the border of the path of totality have frequently reported *progressive* changes in direction of extension.

3. The direction of progress of the bands, which is normal, or perpendicular, to their extension, is also normal to the shadow's edge, progressing either toward or away from it, with several reliable reports recorded of stationary bands.

4. The directions of progress with reference to the shadow may be any of the following:

Pre-totality	*Post-totality*	*Example*
away from	away from	Australia, 1922
away	towards	New York State, 1925
towards	away	New Haven area, 1925
towards	towards	Newport area, 1925
(with the following special cases)		
stationary	away	Canton I., Hellweg, 1937
stationary	stationary	Sumatra, Humphreys, 1901
stationary	stationary	Alcala de Chiver, 1905, Moye and Tramblay

5. Any one mode of motion with respect to the lunar shadow will be maintained for a considerable distance along the eclipse track, but will change, apparently abruptly, into other modes as the shadow travels.

6. It is readily recognizable that the range of speeds of the bands over the ground,—reported most often at from 5 to 10 miles per hour,—is but the hundredth part of the speed with which the shadow spot races across the face of the globe.

The most elaborate attempt at an explanation has been made by G. Horn-D'Arturo of the astronomical observatory of the Royal University of Bologna. In a 181-page pamphlet entitled "Le Ombre Volanti," written in Italian and published in 1924 (which did not come to my attention until July, 1937), this astronomer has given account, as he says, "of all the observational material coming to my knowledge, and accumulated since 1842, also one isolated observation from 1820. The greater part of this material has appeared in annuals and reviews, but I find it possible also to give unpublished data, freely communicated by some observers."

D'Arturo's explanation is foreshadowed in an early paragraph as follows: "Although the phenomenon of the shadow bands possesses in itself only secondary importance, it is able to assume a greater [import] constituting itself the means by which we can reach out to discover some of the peculiarities of the upper air and some of the factors disturbing our [astronomical] observations."

Several lengthy descriptions of the difficulties of the observer and the hampering of the collection of precise and reliable reports might be read with profit by all interested persons. He describes the phenomenon itself in detail and a portion of this I quote here for later reference.

"It is a fact of singular importance to our assertions, based on the reports of the majority of observers, that there is an incessant variation of the width of the bands during the apparition, that is to say, the light bands diminishing in width as the lunar disc occults the sun, and *vice versa* after totality, with increase of the solar crescent, increase also of the width of the light bands; other than that, in considering the contiguous bands [in the moments nearest to totality], the one [kind] light and the other dark, the widening of the light bands occurs at the expense of

the dark ones, and *vice versa,* the narrowing of the light is to the profit of the dark, so that the total width of the pairs remains unaltered.

"In the matter of the orientation of the bands upon the earth's surface, the observers very often find some difficulty, even this element being variable in the course of the apparition; the variation leading to a difference of as much as 90 degrees between the orientation preceding and that following totality, in which interval the longitudinal axis of the bands passes through all the intermediate orientations, following the chord of the solar crescent; there is no lack of cases, however, in which the variation is almost imperceptible and the orientation identical before and after totality; this last case is reported from those places lying upon the line of central eclipse while the incessant variations observed are from points of the earth which occupy the margins of the zone of totality."

Thus, it is evident that D'Arturo had practically concluded in his 1924 publication that the bands are concentric with the moon's shadow, nearly identical with the conclusion reached independently by the present writer at a later date. D'Arturo has backed up this conclusion with geometrical diagrams, description of method of calculation with tabulated results of the same, and also results from plotting tangents to the shadow at the points from which obervers' reports came. He has compared the reports with the two sets of calculations and has found a mean difference of only 12° from his "rigorous" method, and 15° from the graphic method, which latter method has been used by me.

As for the explanation of the bands he says he is "led to conclude that, if the light intervals be considered as due to *real images* of the slender solar crescent, all the displays . . . become fully justified." Continuing, "In order that there be cast upon the earth the real image of a star, its light must necessarily reach the observer through a little hole in a material more or less opaque or capable of absorbing at least a considerable part of its luminous intensity. It is easy to demonstrate the case of a transparent material, by making a little hole in a sheet of celluloid." (Translator's note: The experiment may be tried by any reader, who will form his own conclusions.)

D'Arturo writes: "In the celestial case there may be something of like nature; the terrestrial atmosphere permits, perhaps, to the light, through many gaps, crowded and tiny, a passage reduced by the absorption of a small tribute of light, in such a manner that, compared with the greatest part of the sun behind the interposed lunar body, we distinguish on the earth, fully illuminated, many real images of the crescent-shaped and greatly reduced luminous source, as numerous as are the gaps." He has calculated that these holes, treated as point-like, would exist in a stratum at about 13 km altitude, and to a depth of about 1 km, varying with the clime and season.

He accounts for sinuosities in the bands, like "the fluctuations in a rope, fixed at one end and moved incessantly at the other," likening it to the spectacle every one has seen, looking at a line of strain traversing a

pane of glass. "It is not strange that the constant agitation of the atmosphere constrains the long trajectory of the beams to traverse spaces of diverse density and hence of refracting ability."

D'Arturo takes up the direction of motion of the bands over the ground. Separating the eclipses into two groups, he finds that, out of 122 reports from the Temperate Zone, "93 give the direction as easterly and 29 as westerly; and of 39 observations made in the Torrid Zone, 13 assign it to the east, and 26 to the west." He thinks the preponderance of motion, towards the east in the Temperate Zone, toward the west in the Torrid Zone, is justification for ascribing the motion to the movements of the upper air-streams which are predominantly in these directions. He presents a calculation method intended to show the theoretical direction of motion, and states that of 95 observations of motion easterly, 84 calculations yield the identical quadrant, and 11 contiguous quadrants.

He takes note of a few rare reports of two systems of bands of different width and velocity, proceeding in opposite directions, and suggests that if such is a fact, the oppositeness of motion might be a delusion, due to difference in speed of two sets of bands travelling in the same direction.

He tries to account for the speeds and directions reported by composing the velocity due to the motion of the hypothetical "spiragli" in the wind-belts, and the motion due to the sun's ascent and descent, a westering sun sending rays which, passing through the layer of "spiragli," falls more and more toward the east.

Criticism of D'Arturo's Theory

Any theory covering the shadow bands must account for two of their features, namely (1) their parallelism with respect to the edge of the shadow, and (2) the complications of directions of progress towards, away from, (or stationary), along normals, perpendicular to the edge.

In my opinion, D'Arturo's theory fails in the first particular because it is inconceivable (a) that heterogeneous pin-holes should give orderly, superimposed images of a single source, in parallel, non-overlapping rows, either in the physical laboratory or elsewhere; and (b) that the small crescent images, even if so assembled into large ones, should lie concentric with the lunar shadow's edge. Pinhole images are always reversed. If small crescents are supposed to be assembled into large concentric ones, these crescents should lie, at every location, *convex* with respect to the shadow cone, rather than concave as observed.

The theory fails in the second instance because, if the wind direction and speed are thought to be combined with the apparent solar motion to give the resultant motion of the shadow bands, then the resultant direction of progress should, in the great majority of reports, be the same after totality as before. However, marked, abrupt changes in direction between pre- and post-totality are the most frequently reported. Furthermore, I know of no case, except on the extreme borders of the path of

totality, where any direction changes *during* pre-totality or *during* post-totalityhave ever been observed. On the other hand, the interval between the two sets of band displays is always so brief, it is inconceivable that wind shifts of sufficient magnitude to account for the changes observed, could occur. Even if one grants the remote possibility that the wind might shift the necessary amount, why then, one asks, does the wind not shift thus abruptly while a pre- or post-totality display is going on, instead of waiting for the brief totality period?

(Although in my first paper I intimated that I should give my diffraction theory of shadow bands in Part II, I have limited Part II to a discussion of D'Arturo's paper which at that time had not been read by me. Part III will follow.)

ROOSEVELT HIGH SCHOOL, WASHINGTON, D. C., JULY 25, 1938

The Penumbral Lunar Eclipses of 1940

By ALEXANDER POGO

"In the year 1940 there will be two eclipses, both of the Sun." This statement in *The American Ephemeris and Nautical Almanac*—and analogous statements in all the other nautical almanacs—is, unfortunately, only part of the truth; two fifths of the truth, to be precise. In the year 1940 there will be five eclipses—two of the sun and three of the moon. Just as there must be, during an eclipse season, at least one eclipse of the sun, there must be, during every eclipse season, at least one eclipse of the moon; the minimum number of eclipses in the course

TABLE I

THE PENUMBRAL LUNAR ECLIPSES OF 1940

	March 23	April 22	October 16
Moon enters penumbra	$19^h\ 4^m$ U.T.	$2^h\ 28^m$ U.T.	$5^h\ 54^m$ U.T.
Middle of the eclipse	$19^h\ 48^m$	$4^h\ 27^m$	$8^h\ 1^m$
Moon leaves penumbra	$20^h\ 32^m$	$6^h\ 26^m$	$10^h\ 8^m$
Magnitude of the eclipse	—0.87	—0.09	—0.37
Approach of limb to physical umbra	29′.2	2′.9	10′.8
Moon in the zenith at mid-eclipse: Longitude	65° E	65° W	124° W
Moon in the zenith at mid-eclipse: Latitude	1° S	13° S	9° N

of a calendar year is, therefore, four—two of the sun and two of the moon. During the vernal eclipse season of 1940, the annular solar eclipse of April 7 will be preceded by the penumbral lunar eclipse of March 23, and it will be followed by the penumbral lunar eclipse of April 22; during the autumnal eclipse season of 1940, the total solar eclipse of October 1 will be followed by the penumbral lunar eclipse of October 16. From the point of view of visibility, the three penumbral eclipses of 1940 offer examples of the three possible cases: first, an eclipse which will remain beyond our present means of observation; second, an eclipse which will be very conspicuous; and third, an eclipse

which will be just beyond the limit of naked-eye observation, although well within the reach of the photographic camera.

The penumbral lunar eclipse of 1940 March 23—in the zenith over the Indian Ocean—will remain beyond the limits of observation both of the eye and of the photographic camera. From a "practical" point of view, it will be just as "useless" as the small penumbral eclipses of the sun which occur in the polar regions, and which are conscientiously listed by nautical almanacs and eclipse canons. From a theoretical point of view, the small eclipses at the beginning of the initial penumbral run and at the

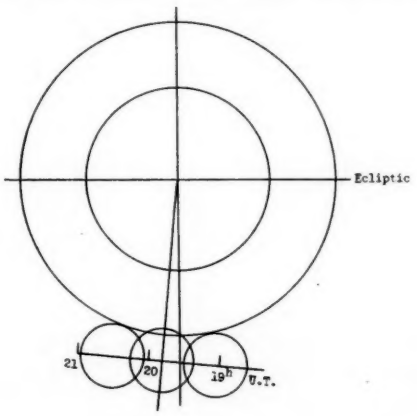

FIGURE 1
THE PENUMBRAL LUNAR ECLIPSE OF 1940 MARCH 23

end of the terminal penumbral run of a saros series are just as important in the case of lunar saros series as in the case of solar saros series; statistical studies of saros series reveal simplicity and symmetry in the structure of the eclipse mechanism; the conspiracy of silence which surrounds penumbral lunar eclipses in textbooks, eclipse canons, and nautical almanacs tends to conceal this simplicity and this symmetry.

The penumbral lunar eclipse of 1940 April 22—in the zenith over South America—will be a very conspicuous celestial phenomenon, visible in all parts of the United States, weather permitting. The southern limb of the moon will pass within three minutes of arc of the physical umbra. The darkening of the southern part of the moon by the inner layers of the penumbra will be clearly visible to the naked eye; it is even possible —though improbable—that the "flat-tire" effect will be visible for a few minutes, if the innermost layers of the penumbral cone are dark enough to hide the southern limb of the moon. The two vernal eclipses of the moon will occur near perigee; on March 23, the moon will be full about 10 hours after perigee; on April 22, the moon will be in opposition about

34 hours after perigee; during these two vernal eclipses, the apparent lunar diameter will be large, and the hourly motion of the moon will be considerable; see Figures 1 and 2.

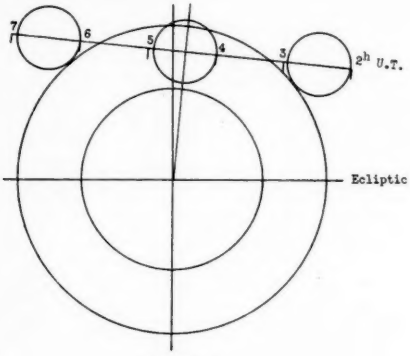

FIGURE 2

THE PENUMBRAL LUNAR ECLIPSE OF 1940 APRIL 22

The penumbral lunar eclipse of 1940 October 16—in the zenith over the eastern Pacific—will be just beyond the limit of naked-eye observation. The northern limb of the moon will pass within almost 11′ of the physical umbra; the limit of visibility corresponds to a distance of about 9′ or 10′. The eclipse may, however, be observed photographically or

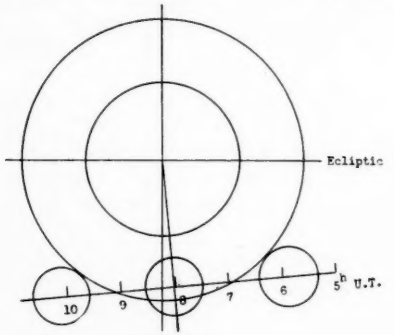

FIGURE 3

THE PENUMBRAL LUNAR ECLIPSE OF 1940 OCTOBER 16

photometrically. The moon will be full, on October 16, about 22 hours after apogee; its apparent diameter will, therefore, be small, and its hourly motion reduced; see Figure 3.

The data tabulated in the first five lines of Table I were obtained by the usual semi-graphic method; the terrestrial coördinates in the last two

lines of the table appeared, originally, in my table of penumbral lunar eclipses, in POPULAR ASTRONOMY, vol. XLV, p. 351.

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The Errors Involved in the Observation of Long-Period Variable Stars

By CLINTON B. FORD

The systematic visual observation of variable stars of long period has now been carried on extensively for more than thirty years, and the files of the American, British, French, Japanese, and other variable star organizations contain a wealth of observational data which will eventually play a large part in our explanation of the behavior of these stars. Thus it is of interest to investigate statistically a large number of such observations, with a view to determining the nature and magnitude of the errors involved and their relation to color and to mean magnitude.

As a preliminary step in this direction, 28 well-observed stars were sel-

TABLE I

THE SELECTED STARS

No.	Design.	Star	Obsns.	Nights
1	001755	T Cas	21	4
2	001838	R And	172	27
3	004958	W Cas	39	7
4	0214*o3*	o Cet	514	76
5	023133	R Tri	22	4
6	024356	W Per	54	10
7	0455*14*	R Lep	52	9
8	0530*o5a*	T Ori	244	52
9	054920a	U Ori	120	21
10	072708	S CMi	89	15
11	194211	R Leo	382	54
12	103769	R UMa	214	34
13	115158	Z UMa	55	11
14	123160	T UMa	55	10
15	123307	R Vir	21	4
16	123961	S UMa	66	12
17	142539a	V Boo	93	15
18	154428	R CrB	1486	202
19	162119	U Her	288	48
20	163266	R Dra	16	3
21	181136	W Lyr	102	18
22	1842*o5*	R Sct	930	129
23	193449	R Cyg	100	17
24	194632	χ Cyg	87	15
25	200938	RS Cyg	200	34
26	201647	U Cyg	190	33
27	210868	T Cep	144	24
28	2338*15*	R Aqr	47	9
28			5803	313

ected from the A.A.V.S.O. Reports in *Harvard Annals*, vol. 104, representing a complete range of color. Mean magnitudes and individual deviations from at least 5 observations per night were determined from all the material available in this volume. Table I gives a list of the selected stars, with the number of observations of each, and the number of nights on which each was observed by at least 5 different observers. The data were tabulated in the following form, so that each observer's deviations could be readily identified:

181136 W Lyr	Color 3.0								No. 21 p. 1
H.A., 104, No.	—III—			—IV—		—VII—			
J.D. 2428	303	308	345	376	431	669	683	695	
Mean m	9.1	8.8	7.8	9.3	11.2	10.6	9.7	9.2	
Obs									
Ah		0		0			+2	+2	
Ca			+3			−2			
Ce								1	
Cm				−1					
W		−1	+2		−2	+1			
Wa						+1			
Wo						−2			

In order to conform with the magnitude scale, the individual deviations, expressed throughout in units of tenths of a magnitude, were taken in the sense [Observed - Mean], so that a *positive* deviation represents an estimate *fainter* than the mean, and *vice versa*. Since the color indices of long-period variables are uncertain, it was decided, for the purposes of this preliminary investigation, to adopt the Osthoff color scale[1] as used on the A.A.V.S.O. charts. This scale is based on visual estimates of color, and hence is also subject to uncertainty. However, its adoption seems justified in the absence of more definitive color data, and the results to follow indicate that the scale is essentially correct.

The prevailing notion that individual observers have definite systematic deviations from the mean is borne out only in a very general way by the data here represented, there being a large number of cases where the deviations show an unmistakable tendency toward abrupt changes from consistently + to consistently — values, or *vice versa*. These variations are not due to any "Magnitude effect," since the mean magnitudes are sensibly constant during the intervals of change. Without tracing the detailed history of each observer's technique, it seems reasonable to conclude that these abrupt changes in deviation are due to the use of different instruments by the same observer, or to changes in location, as *e.g.*, between city and country. In a few cases, where the observer's instrument and location are known to have been unchanged, there are always

[1] *A.N.* 153, p. 141 (1900), 192, p. 85 (1912). See also the article by Lundmark in *Handb. der Astroph.*, V, pp. 367-374.

unchanging systematic deviations for stars of a given color, as would be expected.

Table II shows the method of collecting the data for one star. The

TABLE II

A SAMPLE PAGE OF THE COLLECTED DATA FOR ONE STAR

103769 R UMa 1.6 No. 12
p. 3a

Obs.	Obsns.	Sum Δ	Mean × 10	Sum Δ²	
Ah	13	−13	−10	43	
Ay	2	− 2	−10	4	
B	1	− 2	−20	4	
Ba	1	− 3	−30	9	
Bb	1	− 1	−10	1	
Bs	1	0	00	0	
Bu	3	+ 1	+03	1	
Ch	1	− 1	−10	1	
Cm	1	+ 2	+20	4	
Cr	3	+ 2	+07	6	
Cy	5	− 1	−02	3	
D	6	− 1	−02	19	
Fe	1	+ 5	+50	25	
Fl	2	+ 6	+30	26	
Fn	1	+ 2	+20	4	
Fo	1	+ 1	+10	1	
Fs	1	0	00	0	
Gy	1	+ 2	+20	4	
H	10	+ 7	+07	45	$\sigma^2 = 4.83$
Ha	2	+ 1	+05	1	
Hb	1	− 4	−40	16	$\sigma = 2.20$
He	2	− 1	−05	1	
Hi	9	+22	+24	80	$\sigma = 0^M.22$
Hm	10	+14	+14	48	
Ho	4	+ 3	+08	17	
J	13	− 3	−02	23	
Kg	1	− 2	−20	4	
Kn	2	− 1	−05	5	
Kp	10	−10	−10	44	
LF	1	− 4	−40	16	
Lt	4	+10	+25	28	
Lw	2	− 3	−15	5	
Mb	3	+10	+33	46	
Mc	8	+ 6	+08	40	
Me	2	0	00	2	
Ml	5	− 4	−08	22	
Wh	3	− 5	−17	11	
Wo	1	− 3	−30	9	
Wx	1	− 1	−10	1	
Ze	1	+ 1	+10	1	
	214			1033	

"Sum Δ" column gives the algebraic sum of the deviations, the "Mean × 10" column the mean deviation times 10 (*e.g.*, + 24 = $0^M.24$ faint), and the "Sum Δ^2" column the sum of the squares of the deviations, for each observer. From the total number of observations N and the total squares

of the deviations $\Sigma\Delta^2$ a standard deviation σ was computed for each star by the usual formula,

$$\sigma = \sqrt{\Sigma\Delta^2/N} \qquad (1)$$

It should be emphasized, however, that this σ is a "hybrid," resulting as it does from the lumping together of deviations from a *whole group* of means, one for each night the star was observed. Such a procedure is justified by considering (1) the limited number of observations available per night (never greater than 18, and averaging 8.2), making it impossible to obtain a significant σ from a single mean, (2) the small range of the means (average 2.7 magnitudes, due to the fact that when a star is

TABLE III

THE FINAL DATA

No.	Design.	Star	Obsns.	Obsrs.	Nts.	Mean m	Color	σ_m
8	0530*05*a	T Ori	244	58	52	10.30	0.0	0.30
18	154428	R CrB	1486	89	202	6.08	0.5	0.18
15	123307	R Vir	21	16	4	9.00	1.3	0.18
12	103769	R UMa	214	58	34	8.18	1.6	0.22
14	123160	T UMa	55	32	10	9.42	2.0	0.22
20	163266	R Dra	16	12	3	8.90	2.0	0.22
13	115158	Z UMa	55	19	11	8.00	2.0	0.20
21	181136	W Lyr	102	34	18	9.27	3.0	0.20
22	1842*05*	R Sct	930	73	129	5.80	3.0	0.23
16	123961	S UMa	66	28	12	8.93	3.2	0.26
17	142539a	V Boo	93	33	15	9.05	3.6	0.32
28	2338*15*	R Aqr	47	23	9	8.89	4.3	0.19
10	072708	S CMi	89	31	15	8.48	4.5	0.20
6	024356	W Per	54	25	10	9.65	4.9	0.25
4	0214*03*	o Cet	514	68	76	3.74	5.0	0.22
2	001838	R And	172	48	27	7.56	5.0	0.26
5	023133	R Tri	22	14	4	6.25	5.4	0.25
3	004958	W Cas	39	26	7	10.21	6.0	0.27
23	193449	R Cyg	100	36	17	8.59	6.0	0.33
27	210868	T Cep	144	41	24	7.51	6.3	0.30
19	162119	U Her	288	71	48	8.82	6.5	0.28
24	194632	χ Cyg	87	29	15	8.05	6.5	0.27
11	094211	R Leo	382	73	54	6.99	6.9	0.29
9	054920a	U Ori	120	45	21	7.73	7.0	0.34
1	001755	T Cas	21	14	4	9.32	7.3	0.44
26	201647	U Cyg	190	48	33	9.22	8.4	0.45
7	1455*14*	R Lep	52	25	9	7.33	9.4	0.47
25	200938	RS Cyg	200	45	34	7.64	10.0	0.29
28		Totals	5803	169	313	228.91	131.6	7.63
		Means				8.18	4.70	0.27

faint the number of observations per night is always <5, and no mean is obtained), and (3) the indication, noted in the preceding paragraph, that if there is a "Magnitude effect" influencing the deviations, it is small in comparison with the abrupt changes brought about by external conditions. Thus it becomes apparent that in this particular investigation, "Magnitude effect" has no appreciable influence; it has been ruled out by the practice of taking means from not less than 5 observations per night.

The σ given by equation (1) lumps all the contributing errors together for each star, and, in effect, assumes that all the observations are made at the same time. As such it gives a convenient, albeit general, measure of the error of a single observation, and, as we shall see, it shows a strong correlation with color.

In Table III the final results are given, the stars now being listed in the order of increasing color (0 = white, 10 = red). The column "Mean m" gives the mean of all the nightly means for each star. Figure

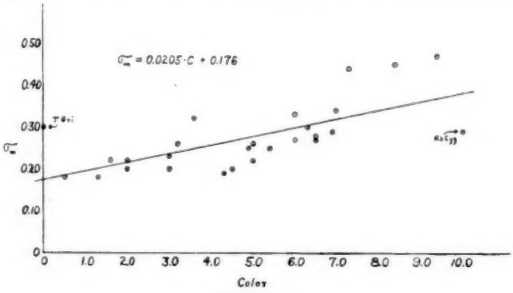


FIGURE 1

1 shows a plot of color against σ_m, for which a linear relation was derived,

$$\sigma_m = 0.0205 \times C + 0.176, \qquad (2)$$

where the notation σ_m is adopted to indicate a standard deviation (in magnitudes) based on a group of means, and C is the color on the Osthoff scale. Figure 2 shows the relation (?) between "Mean m" and σ_m, illustrating the virtual absence of any "Magnitude effect" even when the whole "Mean m" is used against σ_m. Figure 1 bears out the general belief that magnitude estimations of the red stars are subject to larger er-

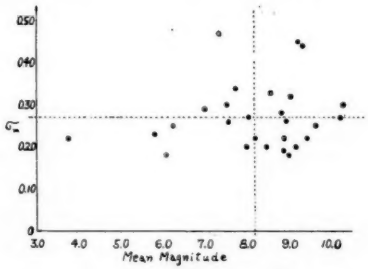


FIGURE 2

rors, in accordance with the Purkinje effect, and equation (2) gives what is believed to be the first general quantitative statement of the relation between redness and error for the long-period variables. In Figure

1, the points representing 053005a T Ori and 200938 RS Cyg are of special interest, since they fall respectively at the two ends of the color scale and deviate conspicuously from the general linear trend of the figure. In the former, the unusually high error is undoubtedly a result of the location of the star in the great Orion Nebula, giving rise to considerable Dove effect[2] due to backgrounds of different intensity in different sized telescopes. As for the latter star, the low error might well be accounted for by the presence of a red comparison star in the field. However, no such star seems to exist.

A number of investigations of individual red long-period variables have been carried out with the careful application of corrections depending upon predetermined personal errors, use of different instruments, change of location, etc. Notable among these is the extensive work of Van der Bilt[3] on 201647 U Cyg, based on a long series of observations by the Variable Star Section of the B.A.A. A treatment of the final results of this work by the method used here yields $\sigma_m = 0^M.22$ from 89 observations, as against $0^M.45$ from 190 observations (uncorrected, of course) by A.A.V.S.O. members. However, there are only 14 British observers represented, as against 48 American. Unquestionably, individual corrections should be applied when sufficient information is available, especially on the red stars; but when a relatively large number of observers is represented, as in the A.A.V.S.O. Reports, σ_m computed from the observations as they stand is a convenient general measure of the errors involved. The mean of all the σ_m's in Table III is seen to be $0^M.27$, which, considering the amount and diversity of the data concerned, is not unduly high, and indicates that as a whole the visual observation of long-period variable stars is a worth-while occupation.

In the future the writer hopes to extend investigations along these lines to include enough observations so that reliable σ_m's can be obtained for each A.A.V.S.O. observer. Thus it will become possible to apply a personal equation correction to each observer's estimates when we come to study them in detail in the future.

University of Michigan Observatory, Ann Arbor, June 4, 1939.

[2] For a discussion of the Dove and Purkinje effects, the reader is referred to Miss Furness' *Introduction to the Study of Variable Stars*, pp. 108-109.

[3] *Memoirs, B.A.A.*, vol. 33 (1937).

A Study of Panchromatic Meteor and Star Trails

By CHARLES HETZLER

ABSTRACT

The incidental trail of a bright meteor in color on a panchromatic plate using a refractor without filter is compared with the trailed images of stars of known spectral and color temperature. The color temperature of the meteor by two methods is over 100,000° indicating that the very blue color is probably due to bright lines such as H and K of ionized calcium. The ptg. mag. of the meteor is calculated as —5, assuming a velocity of 30 degrees per sec. across the line of sight.

INTRODUCTION

Incidental to a survey for infra-red stars the trail of a bright meteor

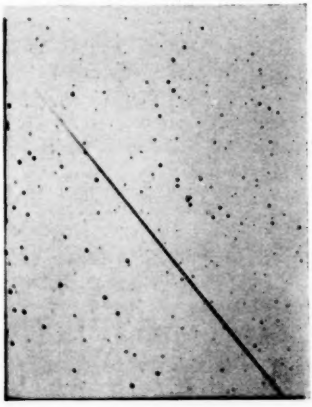


FIGURE 1
A PANCHROMATIC BRIGHT METEOR TRAIL

was photographed on a panchromatic plate (Fig. 1) taken in the manner already described.[1] Although the earlier visual observations of meteor spectra seemed to indicate either a continuous or a bright line spectrum, the evidence from photographs of meteor spectra favors bright line spectra, the continuous spectrum being relatively weak. Nevertheless, occasional meteors may be different, particularly if of very great velocity and brightness. The color index and temperature of the meteor is of

[1] *Ap. J.*, **86**, 514, 1937. The exposure was from 7:45 to 8:45 C.S.T., on Dec. 31, 1936, the declination being 71° and the hour angle 9.5 east.

interest, in any event, and this involves a study of the panchromatic images and trails of various stellar types secured with the Bruce 10-inch refractor.

The Nature of the Panchromatic Images and Trails

The appearance of the images depends upon the focal curve and the focal ratio of the telescope, upon the plate sensitivity, and upon the spectral type. The focal ratio of 5 makes the blue images about one mm. in size when the plates are at the red focus which is 4 or 5 mm. beyond the blue focus. The panchromatic plates are most sensitive in the blue and red, and somewhat less in the green and yellow. All except the very red stars show the out-of-focus blue light as a cytoplasm about the red nucleus. There is always a rather sharp demarcation between the darker center and the peripheral region of uniform intensity. Even the very blue stars (B0 and O) show distinct nuclei. Star *trails* have similar darker centers but the relative intensity between central and peripheral

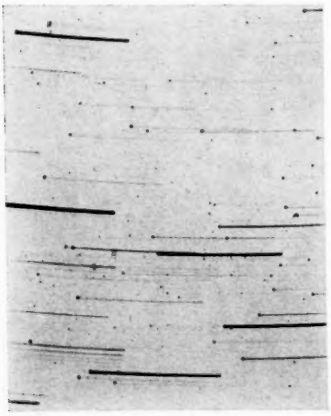


Figure 2
Panchromatic Star Images and Trails

zones is somewhat reduced by the nuclei being more drawn out (Fig. 2). The contrast also becomes less toward the edges of the usable field, since the nuclei seem to be relatively more spread out than the peripheral zones. Comparisons of trails are, therefore, made at the same distance from the optical axis.

To find if the nuclei of the blue stars are partly or wholly due to the ultra-violet, and if the green is intermediate between the red and blue zones, star trails of the Pleiades and other fields were made in ultra-violet through blue light (Eastman 40 plate, Fig. 3, a) and in green light (Eastman I-G plate with Flavazine T filter, Fig. 3, b), all at the red

focus. For all stellar types the blue trails are perfectly uniform, while the green trails are only slightly out-of-focus, being less than one third the diameter of the blue trails. An average star image or trail, therefore, will consist of a uniform out-of-focus blue cell upon which is

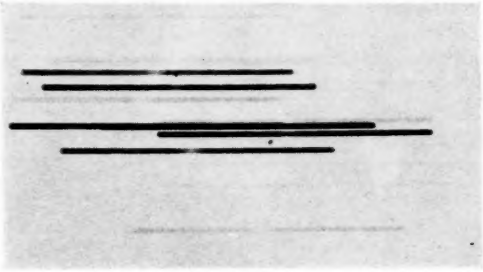


FIGURE 3 (a)
STAR TRAILS IN U.V. THROUGH BLUE

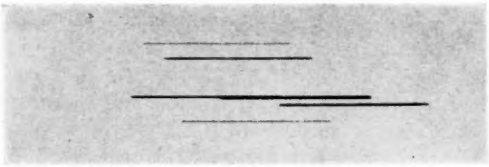


FIGURE 3 (b)
STAR TRAILS IN GREEN-YELLOW

superposed a red nucleus somewhat enlarged by the green-yellow which is slightly out of focus and to which the plates are less sensitive. Redder stars show only the trail of the nucleus but the bluest stars are never without it.

COMPARISON OF METEOR AND STAR TRAILS

The meteor trail is of the exact width of star trails at the same distance from the optical axis and is of practically uniform intensity though fading out toward one end. Near the fainter part of the trail there is a slight indication of a lighter peripheral border and a darker center possibly due to a temperature change, but in general there is no nuclear darkening such as the star trails all show. In particular, a number of O, B0, B3, B5, and A0 stars were trailed and showed, without exception, distinctly stronger nuclei. Trails of the above types of stars are quite similar and definitely bluer than later types and probably it would prove difficult to distinguish a B0 from an A0 by such panchromatic trails, perhaps because the A stars really have a higher color temperature than often supposed.

The Color Temperature of the Meteor

The meteor trail is definitely bluer than those of the bluest stars. Assuming the blue light as effectively of 4500A and the red as of 6000A, and plotting the ratios of the radiation from a black body at these two wave-lengths for various temperatures as ordinates against logarithms

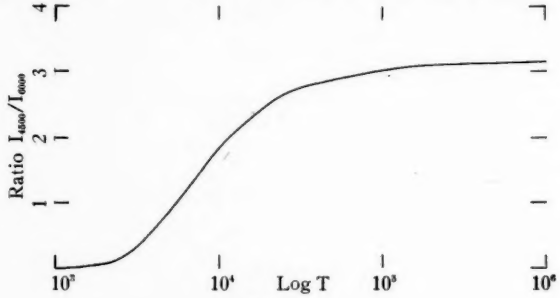


Figure 4

of the temperatures as abscissae (Fig. 4), the curve rises steadily from about zero at 1000° to about 3 at 100,000° after which it flattens and at 1,000,000° is still only 3.15. The steepest part of the curve is below the temperature of the B stars of about 20,000°. The ratio changes by a factor of about 2, or 0.7 mag., from 10,000° to any temperature above about 100,000°; and by a factor of about 1.5, or 0.4 mag., from 20,000°. Since a trail showing no definite nucleus is relatively at least 0.4 mag. weaker in the red than one in which the nucleus is clearly discernible as in all O and B stars, the color temperature of the meteor is at least 100,000°. The color is probably due to strong lines in the blue such as H and K of ionized calcium which are known to occur quite commonly in meteor spectra.

The Brightness of the Meteor

A check on the above color temperature is given by the following estimate of the color index of the meteor. For the ptg. mag. the trail intensity of the meteor is compared with the peripheral zones of blue star trails and matches those of stars of ptg. mag. 5.4 trailed at 62° decl. The intensity integrated over the whole cross-section of the trail is considered for the photovisual magnitude, a match being effected with stars of visual mag. 6.0 at the same decl. (same plate). Another plate at 32° decl. gives these magnitudes as 5.3 and 5.8, respectively. The resulting color index of about —0.5 mag., substituted in the formula

$$T = \frac{7200°}{(I + 0.64)}$$

gives temperatures in general agreement with the previous derivation.

An estimate of the probable magnitude of the meteor can also be made on the basis of the above magnitudes. At 62° decl. stars trail 7°.05 and at 32° decl., 12°.75 per hour. Assuming the average meteor to travel 30° per second across the line of sight gives 15,318 and 8,460 times the speeds of the star trails at the two declinations, or expressed in magnitudes —10.5 and —9.8 times, giving —5.1 and —4.5 as the ptg. mag. of the meteor from star trails taken on two different nights in different parts of the sky. The trails in the first instance were obtained more nearly at the low altitude of the meteor and —5 mag. is, therefore, probably a reasonable estimate of the ptg. mag. of the meteor, though this might be considerably brighter if the speed were greater.

YERKES OBSERVATORY, SEPTEMBER, 1939

The Harvests of Plato

By ROBERT BARKER*

Few lunar formations have received greater attention from advanced observers or have presented a greater puzzle, to this day unsolved, than the magnificent mountain-walled plain of Plato. English observers have been well to the fore; Birt, Webb, Pratt, Williams, Molesworth, Neison, and Elger. In recent years Goodacre and Wilkins and the famous American, W. H. Pickering, have contributed their records of observations of Plato, all with disagreement on many points, leaving an enhanced and unexplained riddle.

The irregular walls, terraced in places, are not high enough to cover the extensive flat floor in shadow very long, and, as the sun increases in altitude, the floor (free from shadow) visibly darkens daily. On the floor are many streaks and spots, the latter being in all probability, craterlets. Twenty spots may be observed, and their true character disclosed, at one lunation. A month later, twenty spots may be recorded again, but many are in different positions, each lunation bringing a record of, perhaps, eight fixed, unchanging spots, with others inconstant, and very difficult to locate.

Pickering at Arequipa actually recorded over 70 craterlets. A suggestion has longe since been made that the changing spots, the darkening floor, the varied light-streaks, the great difficulty of obtaining definition and plain records on an open shadowless floor, are due to vegetable growth, and this is the best explanation of an unanswered lunar problem.

On 1937 December 12, 16¾ hrs. (1⅝ days after First Quarter) I was examining Plato with a power of 420×. The night was cloudless and definition excellent. To my astonishment I saw a strongly marked streak of orange-brown on the west wall, between the points marked A and B on Figure 1, each point marked by a gap in the wall. There was no mis-

*F. R. A. S. and member of British Astronomical Association.

take in this local streak of color, which remained constant whatever the eyepiece and power employed. This streak was not an unbroken patch of color, but consisted of closely interwoven veins, forming a network. My younger son easily confirmed the color. Later, at 21 hrs., it had extended irregularly down the wall, westwards; and the coloring was very strongly defined.

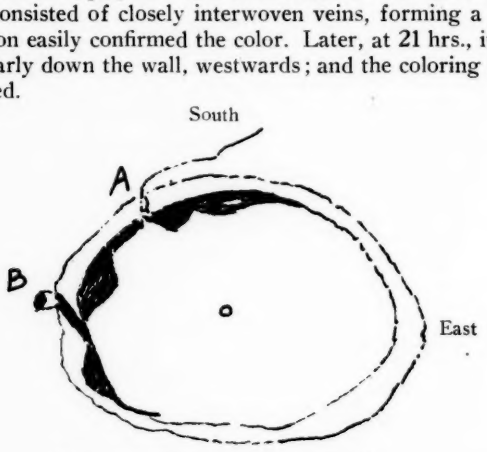


FIGURE 1. PLATO 1937 DECEMBER 12

On 1938 January 16 the colored area was again easily seen; it had plainly extended along the wall beyond A and B, and on the next night it had overflowed down the west wall to the floor, presenting a brownish gold-veined surface of color, irregularly laid on the smooth floor.

Bad conditions prevailed in February, and no definite observations were made. But March, April, and May afforded records of this phenomenon, and revealed varying intensities of color and areas covered; sometimes very faint and restricted to a small locality on the west wall, at other times extended in area from west wall to floor. The writer has noticed curious, inexplicable phenomena in other lunar regions where many small craterlets prevail, which (in some cases) may be due to vapors or exhalations given off by these craterlets. This hypothesis may form an explanation for the "changing" craterlets of Plato, but this recently discovered color streak in behavior is exactly like *quick growing vegetation* (probably of a lowly order) which had 14¾ days in which to complete a cycle of germination, growth, and fructification.

I have obtained full and close confirmation from W. E. Fox (Newark, England), a fine lunar observer, who supplies details of an observation made on 1938 February 14. He writes, "A golden brown spot on Plato's west wall, seen at once—often extending along the inner south wall—very prominent, with a yellowish glow spreading over floor without a definite boundary—whole floor yellowish brown, apparently obliterating the floor—no sign of reddish brown on southwest wall, though the most intense part of yellow glow was originally near that spot." He notices distinct variations in depth and area covered in March and April, his

dates agreeing with mine. "Just a trace of dusky brown at inside foot of west wall in the original position indicated by R. Barker."

These observations seem to bear strong witness to the first definite trace of *color* ever seen on the moon, though the writer has seen very faint patches of yellow in the locality of Proclus at irregular, long-spaced intervals, always under very high illumination.

Already there is evidence that the "harvests" of Plato form in their variation a parallel to harvests on earth, and the writer hopes that this easily seen color area may lead observers to renewed study of Plato and other areas; for only by ordered seeing, care, and extreme patience, can lunar changes be recorded.

Telescope used: Calver 12.6-inch, clock-driven equatorial.

Planetary Phenomena in 1940

By R. S. ZUG

Note: Universal or Greenwich Civil Time is employed unless otherwise stated. This is Standard Time in England, and is reckoned from Greenwich midnight through 24 consecutive hours. To obtain Eastern Standard Time subtract 5 hours from Greenwich Civil Time. To obtain Central Standard Time, subtract 6 hours, etc. The data utilized in this article are taken chiefly from the *American Ephemeris and Nautical Almanac*. The position of Pluto was secured from the *Berliner Astronomisches Jahrbuch*. Information concerning penumbral lunar eclipses in 1940 was taken from the article by Alexander Pogo, "The Penumbral Lunar Eclipses of 1940," in this issue of POPULAR ASTRONOMY. The chart of the *Visibility of the Planets* was prepared by Mr. John Phillips.

ECLIPSES

There will be two solar eclipses in 1940, one an annular eclipse, and one a total eclipse. In addition, there will be three penumbral lunar eclipses, as pointed out by Alexander Pogo on p. 6 of this issue of POPULAR ASTRONOMY. Pogo has made a very good point, it seems, in his contention that penumbral lunar eclipses have in the past received insufficient attention, both observationally and theoretically. He has described the three penumbral lunar eclipses of 1940 quite fully in the article referred to above. The first of these, to occur March 23, is unobservable. In the third, which occurs October 16, the moon's limb will pass 11′ from the physical umbra, so that the eclipse will not be visible to the unaided eye. The second of the penumbral lunar eclipses, however, which will occur April 22, is visible to the naked eye, and is therefore of immediate interest to observers. A description of this eclipse is given below, along with that for the two solar eclipses.

I. *An annular eclipse of the sun will occur April 7, 1940.* The path of the annular eclipse begins in the Pacific Ocean a little west of the international date line in latitude 4° S. The eclipse track then proceeds eastward and northward, touching Christmas Island, and finally the Lower California Peninsula and into Mexico. The city of Chihuahua, Mexico, seems centrally located in the path, which then crosses into Texas and the gulf states of the United States. Many of the larger gulf coast cities of the United States are in or near the path of the annular

eclipse, which will last for about six minutes for those centrally located. The path leaves the east coast of the United States near Jacksonville, Florida, to proceed in an easterly direction some thousand miles out into the Atlantic Ocean. Here the axis of the shadow cone of the moon loses contact with the earth at sunset. The

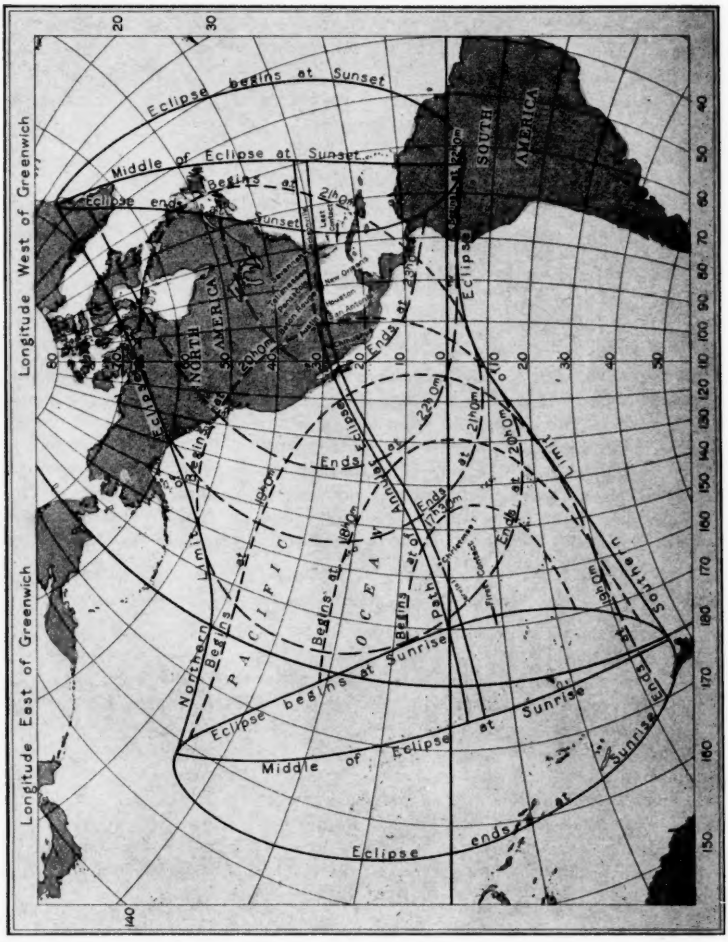


FIGURE 1. THE ANNULAR ECLIPSE OF APRIL 7, 1940. *(From the American Ephemeris.)*

eclipse will be visible as partial over a large portion of the Pacific Ocean, North America except Alaska, the northern portion of South America, and the western portion of the Atlantic Ocean. Last contact occurs at sunset off the east coast of Florida.

In the western portion of the United States, the partial eclipse will last from

about 11:30 A.M. to 2:30 P.M. Pacific Standard Time. In the mountain states the corresponding interval is from about 1:00 P.M. to 4:00 P.M. Mountain Standard Time; in the central states, from 2:15 P.M. to 5:00 P.M. Central Standard Time; and in the eastern states, from 3:30 P.M. to 6:30 P.M. Eastern Standard Time. For any particular locality, the times of first and last contacts can be estimated with the aid of Figure 1, with an uncertainty of but a few minutes. The magnitude of the eclipse in the United States varies from 93%, for points located in the path of the annular eclipse, to about 35% in the state of Washington. Values for representative points, in terms of the fraction of the sun's diameter obscured at maximum eclipse, are: California, 0.7; Colorado, 0.7; Minnesota, 0.6; Massachusetts, 0.6; New Mexico, 0.8; Arkansas, 0.8; North Carolina, 0.8. These values vary somewhat within a state, depending on the longitude and latitude. Local circumstances are given for eighty cities in the United States on pp. 587-588 of the *American Ephemeris and Nautical Almanac* for 1940.

Circumstances of the Annular Eclipse of April 7, 1940:

	G.C.T. d h m	Longitude ° ′	Latitude ° ′
Eclipse begins	April 7 17 17.4	+167 46	— 8 39
Central eclipse begins	7 18 25.6	—174 37	— 4 2
Central eclipse at local app. noon	7 20 28.6	+126 39	+20 20
Central eclipse ends	7 22 16.1	+ 59 33	+29 13
Eclipse ends	7 23 24.3	+ 77 19	+24 37

II. *A penumbral lunar eclipse will occur April 22, 1940,* observable in North and South America. The southern limb of the moon will approach to within three minutes of arc of the umbral shadow of the earth. The southern limb of the moon should be conspicuously diminished in intensity at the time of closest approach to the umbral cone. Circumstances of the eclipse are given below, taken from the article by Pogo. For completeness, circumstances for the other two penumbral lunar eclipses are also listed, even though these two eclipses will be quite unobservable to the naked eye.

Circumstances of the Penumbral Lunar Eclipses of 1940:

	Eclipse of March 23 h m	Eclipse of April 22 h m	Eclipse of Oct. 16 h m
Moon enters penumbra	19 4	2 28	5 54
Middle of the eclipse	19 48	4 27	8 1
Moon leaves penumbra	20 32	6 26	10 8
Closest approach of limb to umbra	29.2	2.9	10.8
Moon in the zenith at mid-eclipse — Longitude	—65°	+65°	+124°
Moon in the zenith at mid-eclipse — Latitude	— 1	—13	+ 9

III. *A total eclipse of the sun will occur October 1, 1940.* The path of totality begins near Tumaco, Colombia, where the eclipse will be visible at sunrise, and proceeds east and south across the Amazon valley. The path of totality leaves the continent of South America at Pernambuco (Recifé) on the east coast of Brazil, and crosses the Atlantic Ocean and Cape of Good Hope, South Africa. The duration of totality at Pernambuco will be 4 minutes 51 seconds, and in South Africa, about 3 minutes, 30 seconds. The *British Nautical Almanac* Office has prepared a Supplement to the *Nautical Almanac* for 1940 entitled "The Total Solar Eclipse of 1940 October 1," giving full details of the eclipse path, and of the adjustment of instruments for stations near the central line, according to a statement on p. 6 of

FIGURE 1. THE ANNULAR ECLIPSE OF APRIL 7, 1940. *(From the American Ephemeris.)*

The Handbook of the British Astronomical Association for 1940.

The eclipse will be seen as partial over a considerable portion of South America, South Africa, and the Atlantic Ocean, as illustrated in Figure 2. At Panama, Panama,, the eclipse will be in progress at sunrise, at which time the magnitude of the eclipse will be 82%.

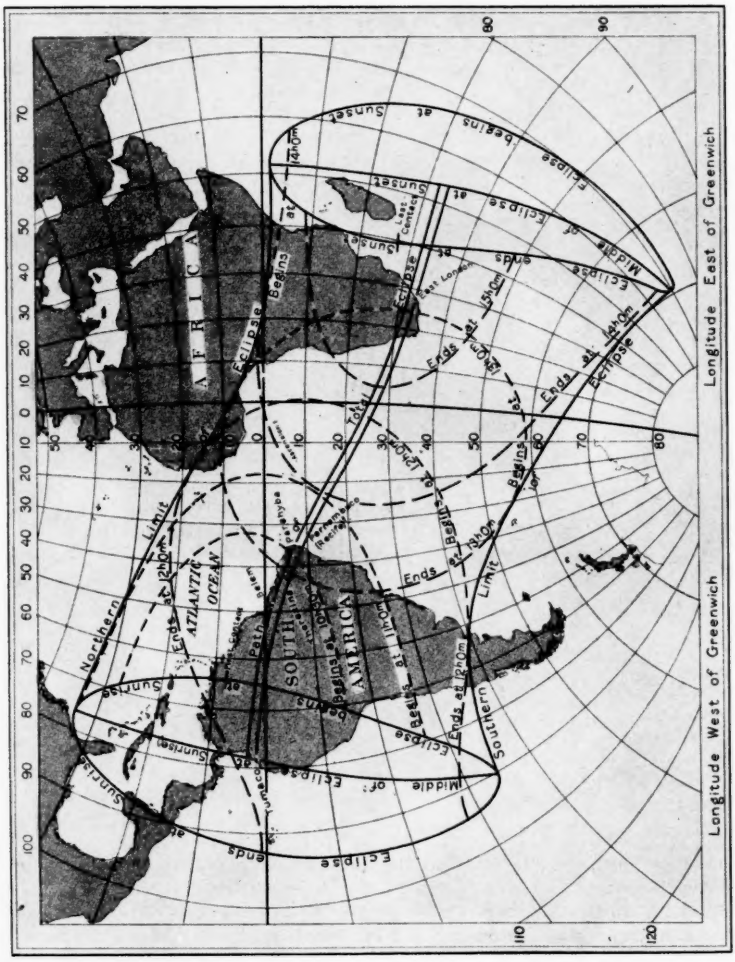


FIGURE 2. THE TOTAL ECLIPSE OF OCTOBER 1, 1940. *(From the American Ephemeris.)*

The eclipse of October 1, 1940, is one of a series which is of considerable interest from the point of view of eclipse history. This is pointed out by Lewis J. Boss, in a note which will appear in POPULAR ASTRONOMY, as the time of the eclipse draws nearer.

Circumstances of the Total Eclipse of the Sun of October 1, 1940:

	G.C.T. d h m	Longitude ° ′	Latitude ° ′
Eclipse begins	October 1 10 8.2	+64 10	+ 7 58
Central eclipse begins	1 11 4.3	+78 30	+ 2 41
Central eclipse at local app. noon	1 12 52.0	+15 36	−19 2
Central eclipse ends	1 14 22.9	−53 47	−32 36
Eclipse ends	1 15 19.0	−39 21	−27 20

Planets

Visibility of the Planets. The visibility of the planets for any date may be found from examination of Figure 3, prepared by Mr. John Phillips. This chart, similar to those which have appeared in this magazine for the past five years, shows for any date the difference in right ascension between each planet and the sun. If the graph of a planet lies to the right of the zero line on a given date, the planet is a morning star. If to the left, then the planet is an evening star. A planet should be one or two hours east or west of the sun to be easily observable in the evening or morning sky, as the case may be. Where the graph of a planet intersects the 12-hour line, the planet is in opposition, and the corresponding ordinate gives the date of opposition. Where a graph crosses the zero line, conjunction with the sun is indicated. When the graph pertaining to a superior planet crosses the zero line, the planet is, of course, in conjunction, on the corresponding date. An inferior planet may be in superior or inferior conjunction, depending on whether it had previously been a morning, or evening, star, respectively. Where two graphs intersect, the corresponding planets are in conjunction with one another on that date. The declination of each planet is indicated at intervals along the respective curves, usually at points corresponding to dates upon which the declination attained an integral number of degrees. Where the declination is given to the tenth of a degree, it usually signifies that a maximum or minimum was reached on the day in question.

It is of noteworthy interest that around February 29, at the time of the greatest eastern elongation of Mercury, all five of the bright planets of naked-eye visibility may be found in the evening sky, shortly after sunset, situated within three hours of one another in right ascension. As can be verified with the aid of Figure 3, they will be lined up from west to east along the ecliptic in the following order: Mercury (magn., 0.0), Jupiter (magn., −1.7), Venus (magn., −3.6), Saturn (magn., +0.7), and Mars (magn., +1.4). The first four, as listed, will be situated in the constellation Pisces, while Mars will be in Aries. In addition, the planet Uranus (magn., +6.0) will be located in Aries, less than one hour to the east of Mars.

Mercury. Mercury will be a conspicuous evening star, for observers in the northern hemisphere, around February 28 and June 24, dates of greatest eastern elongation. The planet will not be so conspicuous at greatest eastern elongation October 20, due to its southerly declination at that time. The planet should be quite prominent in the morning sky around August 10, shortly before sunrise. The greatest elongations of Mercury from the sun during 1940 are listed below, with the stellar magnitude of the planet at each elongation.

A conjunction of Mercury and Venus will occur June 12, 2^h, at which time Mercury will pass 1° 24′ to the north of Venus. A conjunction with Mars will occur June 17, 1^h, with Mercury 0° 26′ to the north of Mars.

FIGURE 2. THE TOTAL ECLIPSE OF OCTOBER 1, 1940. *(From the American Ephemeris.)*

Longitude West of Greenwich — Longitude East of Greenwich

VISIBILITY OF THE PLANETS FOR 1940

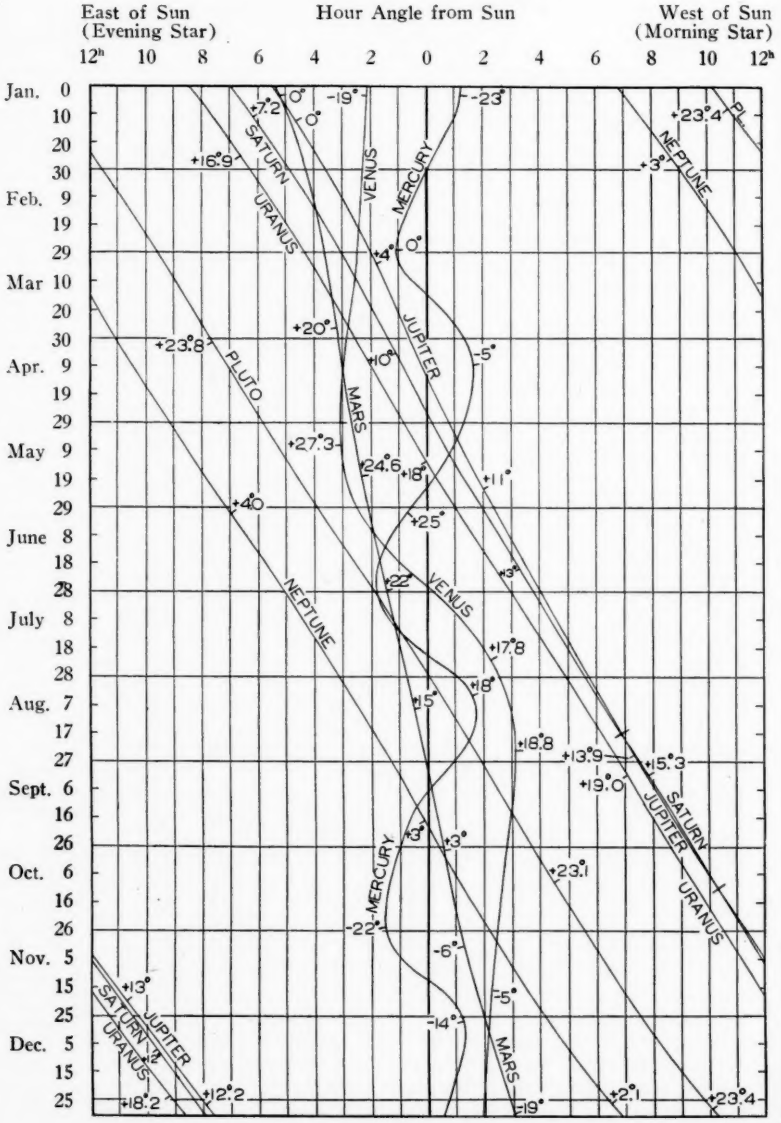


FIGURE 3

Greatest Elongations of Mercury from the Sun in 1940:

Eastern Elongation (Evening Star)			Western Elongation (Morning Star)		
Date d h	G.E. East ° ′	Stellar Magn.	Date d h	G.E. West ° ′	Stellar Magn.
Feb. 28 11	18 9	−0.2	Apr. 12 9	27 40	+0.6
June 24 14	25 18	+0.7	Aug. 10 10	18 57	−0.2
Oct. 20 16	24 30	+0.2	Nov. 28 22	20 11	−0.2

A transit of Mercury over the sun's disk is predicted for November 11-12, 1940. The ingress is visible in North America, except for the northeastern part, most of South America, the Pacific and Antarctic Oceans, and Australia. The egress will be visible in the extreme northwestern part of North America, the Pacific Ocean except the extreme eastern part, Australia, Polynesia, the Antarctic and Indian Oceans, and Asia except the extreme western part. The four geocentric times of contacts, the time of least distance between the centers of the sun and Mercury, together with the corresponding angles of position of Mercury from the north point of the sun's disk, are tabulated below.

Transit of Mercury, November 11-12, 1940:

	Date d h m s	Angle of Position from the North Point
Ingress, exterior contact	Nov. 11 20 49 16.6	91°.9 to E
Ingress, interior contact	11 20 51 5.0	91.6 to E
Least distance of centers, (6′.14)	11 23 21 34.3	
Egress, interior contact	12 1 52 7.5	43.5 to W
Egress, exterior contact	12 1 53 55.9	43.7 to W

The times of contacts for any particular locality may differ from the geocentric times, depending on the observer's longitude and latitude on the earth's surface. In the United States, where only the ingress will be visible, the first contact (external ingress) will occur about $20^h\,49^m$, G.C.T., and the second (internal ingress) about $20^h\,51^m$ G.C.T. The Greenwich Civil Time of the four contacts for any point on the earth's surface may be computed to the nearest tenth of a second of time from the following four formulas, where ϕ denotes the observer's latitude, and λ his longitude west of Greenwich:

$$\text{Ing. ext.} = 20^h\,49^m\,16^s.6 + 1^s.25 \sin\phi - 45^s.13 \cos\phi \cos(44°.9 - \lambda)$$
$$\text{Ing. int.} = 20^h\,51^m\,5^s.0 + 1^s.07 \sin\phi - 45^s.22 \cos\phi \cos(45°.4 - \lambda)$$
$$\text{Egr. int.} = 1^h\,52^m\,7^s.5 + 31^s.34 \sin\phi + 32^s.37 \cos\phi \cos(285°.4 - \lambda)$$
$$\text{Egr. ext.} = 1^h\,53^m\,55^s.9 + 31^s.16 \sin\phi + 32^s.43 \cos\phi \cos(286°.0 - \lambda)$$

Venus. Venus will be an evening star during the first part of 1940. The brilliancy of the planet will increase from stellar magnitude −3.3 on January 1 to −4.2 on May 20, the date of greatest brilliance while an evening star. The planet will be at greatest eastern elongation, 45° 44′ from the sun, on April 17, 12^h. Inferior conjunction with the sun will occur June 26, 21^h. At inferior conjunction, Venus will be situated 2° 46′ south of the center of the sun's disk. After inferior conjunction, Venus will be a morning star, and will attain greatest brilliance as such on August 2, when its stellar magnitude will be −4.2. The greatest western elongation of the planet will be 45° 57′, and will occur September 5, 13^h. Data of interest to observers are tabulated below.

VENUS (EVENING STAR)

Date, 1940	Distance from earth in miles	Angular Diameter	% of disk seen Illuminated	Stellar Magnitude
January 1	131,040,000	11".9	0.88	—3.4
January 31	116,330,000	13.4	0.81	—3.5
March 1	98,851,000	15.8	0.72	—3.6
April 1	78,045,000	20.0	0.59	—3.8
May 1	56,221,000	27.8	0.43	—4.1
June 1	35,239,000	44.3	0.18	—4.2
June 26, 21^h	26,921,000	58.0	0.003	—2.9

June 26, 21^h, Inferior Conjunction with the Sun.

VENUS (MORNING STAR)

July 1	27,177,000	57.5	0.01	—3.3
August 1	40,764,000	38.3	0.25	—4.2
September 1	62,270,000	25.1	0.48	—4.0
October 1	83,439,000	18.7	0.63	—3.8
November 1	103,666,000	15.1	0.74	—3.6
December 1	120,793,000	12.9	0.83	—3.5
December 31	135,066,000	11.6	0.90	—3.4

A number of conjunctions of Venus with other planets will occur during the year, as listed below.

CONJUNCTIONS OF VENUS WITH OTHER PLANETS

Date, 1940 G.C.T. ^{h}	Conjunction with	Angular Separation	Venus N. or S. of Other Planet
Feb. 20, 22	Jupiter	1° 0′	N
Mar. 8, 14	Saturn	3 22	N
Mar. 26, 14	Uranus	2 31	N
Apr. 11, 0	Mars	2 11	N
June 7, 6	Mars	0 22	N
June 12,	Mercury	1 24	S
Oct. 29, 21	Neptune	0 11	N
Dec. 2, 12	Mars	1 17	N

Two occultations of Venus by the moon will occur during 1940, on July 31 and on November 26. The limiting parallels of latitude within which the occultation is visible are, in the first case, 12° N to 72° N, and in the second, 39° S to 26° N. The occultation of Venus of November 26 will not be visible from the United States as such, but will appear as a close approach of Venus to the northern limb of the moon. The occultation of July 31, however, will be nicely observable from the United States. At longitude 91° W and latitude 40° N, the times of immersion and emersion are, respectively, 4:17 P.M. and 4:57 P.M. (Central Standard Time). For longitude 120° W and latitude 36° N, the corresponding times are 2:16 P.M. and 3:17 P.M. (Pacific Standard Time).

Earth. The earth is in perihelion January 2, 6^h, and in aphelion July 4, 10^h. Spring begins March 20, 18^h 24^m, at the instant the center of the sun's disk reaches the vernal equinox. Summer begins June 21, 13^h 37^m, when the sun reaches the summer solstice. Fall begins with the passage of the autumnal equinox September 23, 4^h 46^m, and winter, December 21, 23^h 55^m, when the sun passes the winter solstice.

Mars. Mars will be relatively inconspicuous in 1940. On January 1, 1940, it will be an evening star of stellar magnitude +0.7, not far from the vernal equinox, and 119,060,000 miles from the earth. Its elongation from the sun and its

apparent brightness are gradually decreasing until August 30, when the planet reaches conjunction with the sun. Thereafter it will be situated in the morning sky, gradually increasing in elongation from the sun and in apparent brightness. Data are listed below:

Date, 1940	Distance from earth in miles	Angular Diameter	Stellar Magnitude
January 1	119,060,000	7".3	+0.7
August 30	284,570,000	3.4	+2.0
December 31	201,770,000	4.3	+1.8

It is interesting to note that this year, at conjunction, Mars will be situated at almost its maximum distance from the earth, both planets being close to their respective aphelion points at the time. (Mars reaches aphelion August 26; the earth, July 4.)

The apparent motion of Mars is direct throughout the year. During 1940 Mars will move eastward three quarters of the way around the ecliptic, from its initial position near the vernal equinox. By the end of the year it will be in the constelation Libra. Mars is in conjunction with the other planets during 1940, as listed below.

CONJUNCTIONS OF MARS WITH OTHER PLANETS

Date, 1940 G.C.T. h	Conjunction with	Angular Separation	Mars N. or S. of Other Planet
Jan. 7, 15	Jupiter	1° 10′	N
Feb. 13, 8	Saturn	2 59	N
Mar. 16, 18	Uranus	1 6	N
Apr. 11, 0	Venus	2 11	S
June 17, 1	Mercury	0 26	S
July 10, 0	Mercury	4 24	N
Sept. 28, 23	Neptune	0 13	S
Dec. 2, 12	Venus	1 17	S

Jupiter. Jupiter will be seen in the evening sky during the first part of 1940. Conjunction with the sun occurs April 11, after which the planet will be situated in the morning sky. Western quadrature will occur August 7, and opposition with the sun on November 3. The stellar magnitude of Jupiter will be —2.0 on January 1. The planet then slowly diminishes in apparent brightness until conjunction in April. After conjunction the brightness of the planet icreases, the stellar magnitude reaching —2.4 at the time of opposition in November.

During the year, Jupiter moves eastward from a point near the vernal equinox in Pisces into the constellation Aries. The apparent motion is direct until September 4, after which it is retrograde for the remainder of the year. After Jupiter has reached conjunction with the sun, its apparent path resembles that of Saturn quite closely, so that during the summer and fall, the two planets will be situated near one another in the morning sky. Two conjunctions of Jupiter and Saturn will occur: August 15, 13^h, with Jupiter 1° 17′ north of Saturn; and October 11, 23^h, with Jupiter 1° 17′ again to the north. Both planets will be in western quadrature on August 7, and in opposition on November 3. Conjunctions of Jupiter with Mars and Venus will occur on January 7 and on February 20, respectively.

Four occultations of Jupiter will occur on the following respective dates: June 2, June 30, November 13, and December 11, none of them visible from the United States.

Saturn. Saturn will be an evening star until conjunction with the sun on April 24. After this date it will be a morning object, reaching western quadra-

ture on August 7. Opposition with the sun will occur on November 3. The planet's apparent motion carries it from the constellation Pisces into Aries during the course of the year. After conjunction the planet will be situated not far from Jupiter, in the morning sky, as described above. The stellar magnitude of Saturn varies from +0.6 on January 1 to 0.0 at opposition, and then to +0.4 on December 31.

The view of the ring system will be somewhat better than in 1939. On January 1, 1940, the angular dimensions of the major and minor axes of the outer ellipse of the outer ring will be, respectively, 41".7 and 9".8; at opposition on November 3, the corresponding values will be 45".7 and 15".2. The southern side of the ring system is visible from the earth.

Saturn will be occulted by the moon on June 3, June 30, July 28, September 20, October 18, November 14, and December 11. None of these occultations will be visible from the United States, except that of December 11, which will be visible south of latitude 36° N.

Uranus. Uranus will be in conjunction on May 12, and in opposition on November 16. Eastern quadrature occurs on February 7, and western quadrature on August 19. The apparent path of the planet in 1940 extends from the constellation Aries into Taurus, and then back into Aries again. Uranus is in slow retrograde motion until January 6, and, during January and February, can be found a little west of, and about 40′ south of, the 6.3 magn. star, 53 Arietis. The planet's motion is then direct, in almost a straight line path, and about May 20 it enters the constellation Taurus. This eastward motion ceases on September 1, at a point 47′ west of, and 29′ south of, the 5.5 magn. star, 13 Tauri. The planet then retrogresses, and by December 31, will have back-tracked over almost the same nearly straight line path, into the constellation Aries, where it will be during the first part of 1941.

On June 4, Uranus will be situated 14′ south of a 6.4 magn. star, B.D.+18°484. This will provide a good opportunity for telescopic comparison of Uranus with a star of similar brightness. On June 25, the planet will be situated 10′ south of the 8.3 magn. star, B.D.+18°494, and on July 26 it will be situated about 1′ south of the 9.5 magn. star, B.D.+18°510.

Neptune. Neptune is now in the constellation Virgo. The dates of opposition and conjunction with the sun are, respectively, March 14 and September 18. The path of Neptune from January 1 to August 1, 1940, is illustrated in Figure 4. The star background has been copied from the B.D. (Bonn Durchmusterung) star maps, and the path of Neptune superimposed, allowance being made for precession. The position of Neptune for the first of each month is indicated. The smallest dots represent stars of from 9.5 to 10.0 magnitude. Two stars, 89 Leonis, magn. 5.8, and β Virginis, magn. 3.8, which are present on detailed star charts such as *Norton's,* are shown on the chart. The chart is arranged for use with an inverting telescope, and, for comparison with the field of view in the eyepiece, the chart should be oriented so that the "up" direction points toward the north celestial pole. Neptune will come within 4′ or 5′ of several faint stars during 1940, as can be verified from Figure 4.

Pluto. Pluto is in opposition with the sun on January 24, and is located in the constellation Cancer, not far from the star λ Cancri. The stellar magnitude of Pluto is +15.0, so that a large telescope, probably one of at least 20 inches aper-

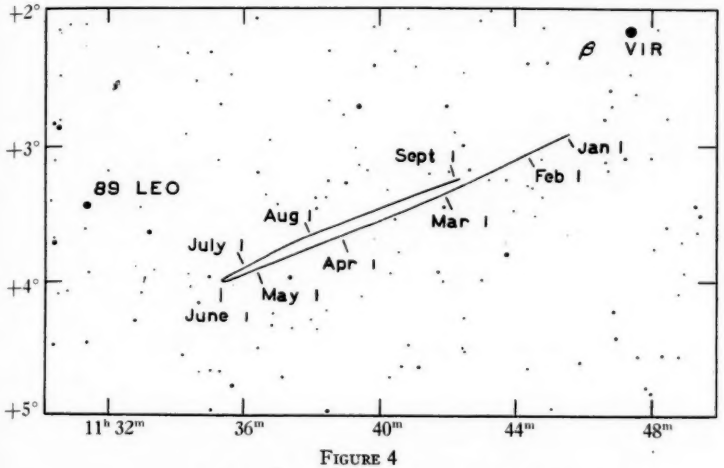


FIGURE 4

THE PATH OF NEPTUNE AMONG THE STARS FROM JANUARY TO SEPTEMBER, 1940.

ture, is needed for locating the planet by visual means. A chart showing the configuration of faint stars in the region of Pluto would be almost a necessity for positive identification of the planet. It does not seem worth while to prepare such a chart for POPULAR ASTRONOMY, since very few observers have access to such a large telescope.

CALENDAR OF PLANETARY PHENOMENA IN 1940

Date	Phenomenon
Jan. 2	Earth at perihelion.
Feb. 28	Mercury, greatest elongation. (Evening star)
Feb. 29	Six planets visible in evening sky, around this date.
Mar. 14	Neptune in opposition.
Mar. 20	Spring begins, $18^h\ 24^m$.
Apr. 7	Annular eclipse of the sun.
Apr. 17	Venus, greatest elongation. (Evening star)
Apr. 22	Penumbral lunar eclipse.
May 20	Venus, greatest brilliance. (Evening star)
June 2	Occultation of Jupiter. (Invisible in U.S.)
June 3	Occultation of Saturn. (Invisible in U.S.)
June 4	Close approach of Uranus to a 6.4 magn. star. (Ang. sep. 14′)
June 7	Conjunction of Venus and Mars. (Ang. sep. 22′)
June 17	Conjunction of Mars and Mercury. (Ang. sep. 26′)
June 21	Summer begins, $13^h\ 37^m$.
June 24	Mercury, greatest elongation. (Evening star)
June 25	Close approach of Uranus to an 8.3 magn. star. (Ang. sep. 10′)
June 26	Venus at inferior conjunction.
June 30	Occultation of Jupiter. (Invisible in the U.S.)
July 4	Earth at aphelion.
July 26	Close approach of Uranus to a 9.5 magn. star. (Ang. sep. 1′)
July 28	Occultation of Saturn. (Invisible in the U.S.)
July 31	Occultation of Venus.
Aug. 2	Venus, greatest brilliance. (Morning star)
Aug. 10	Mercury, greatest elongation. (Morning star)
Sept. 5	Venus, greatest elongation. (Morning star)

Date	Phenomenon
Sept. 20	Occultation of Saturn. (Invisible in U.S.)
Sept. 23	Fall begins, $4^h\ 46^m$.
Oct. 1	Total eclipse of the sun. (Invisible in U.S.)
Nov. 3	Jupiter in opposition.
Nov. 3	Saturn in opposition.
Nov. 11-12	Transit of Mercury.
Nov. 13	Occultation of Jupiter. (Invisible in U.S.)
Nov. 14	Occultation of Saturn. (Invisible in U.S.)
Nov. 16	Uranus in opposition.
Nov. 26	Occultation of Venus. (Visible in U.S. south of latitude 26° N.)
Dec. 11	Occultation of Jupiter. (Invisible in U.S.)
Dec. 11	Occultation of Saturn. (Visible in U.S. south of latitude 36° N.)
Dec. 21	Winter begins, $23^h\ 55^m$.

Planet Notes for February, 1940

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will be moving through the constellations Capricornus and Aquarius during February. The motion is northeasterly and will take the sun into Aquarius on February 17. The coördinates of the sun for February 1, and February 29, respectively, are: $\alpha = 20^h\ 53^m.7$, $\delta = -17°\ 28'.8$; $\alpha = 22^h\ 43^m.4$, $\delta = -8°\ 6'.0$.

Moon. Phenomena of the moon will occur as follows:

		h	m
New Moon	Feb. 8	7	45
First Quarter	16	12	55
Full Moon	23	9	55
Last Quarter	Mar. 1	2	35
Apogee	Feb. 11	2	
Perigee	23	22	

Mercury. Mercury will be an evening star during February, and will reach greatest eastern elongation from the sun of 18° 9′ on February 28, 11^h. While Mercury is near greatest elongation, an unusual configuration of bright planets will be visible in the evening sky. All of the planets visible to the unaided eye, including Uranus, will be evening stars! They will be situated along the ecliptic, from west to east, in the following order: Mercury, Jupiter, Venus, Saturn, Mars, Uranus.

Venus. Venus will be a bright evening star of magnitude —3.5 during February. On February 20, 22^h, Venus will be in conjunction with, and 1° 1′ north of, the planet Jupiter.

Mars. Mars is in the evening sky, and drawing closer to the sun in its apparent motion. The angular diameter of the planet has diminished to about 5″.5, and its stellar magnitude is now about +1.3. Mars will be located about 3° north of Saturn on February 13.

Jupiter. Jupiter will be an evening star of stellar magnitude —1.7 during February.

Saturn. Saturn is an evening star. Its magnitude during February will be about +0.7.

Uranus. Uranus is in the constellation Aries, and is moving slowly eastward in direct motion. Eastern Quadrature occurs on February 7. It can be found during February a little west of, and about 40′ south of, the 6.3 magn. star, 53 Arietis.

Neptune. Neptune is situated in the constellation Virgo just north of the star β Virginis. It may befound with the aid of the chart illustrating its apparent motion, which appears on page 31 of this issue of POPULAR ASTRONOMY.

Occultation Predictions

(Taken from the *American Ephemeris*)

Date				IMMERSION Greenwich		IMMERSION a	IMMERSION b	IMMERSION Angle E from	EMERSION Greenwich		EMERSION a	EMERSION b	EMERSION Angle E from
				h	m	m	m	°	h	m	m	m	°
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′.													
Feb.	2	88	B.Sco	6.4	7	29.6	—0.3	+0.7	114	8	34.2	—0.9	+1.1	274
	16	180	B.Tau	6.1	23	54.3	—1.8	+3.0	32	0	49.3	—1.9	—3.4	311
	17	193	B.Tau	6.3	2	27.9	—1.2	—0.7	77	3	37.8	—0.6	—1.7	278
	19	BD+18°1112		6.4	5	38.3	—0.7	—0.7	69	6	30.5	+0.1	—2.2	308
	19	124	H³Ori	5.7	7	7.6	0.0	—1.2	90	8	0.1	+0.4	—1.4	286
	21	BD+14°1850		6.4	6	54.5	—0.5	—1.8	123	7	52.3	—0.4	—1.4	272
	21	60	Cnc	5.7	22	34.7	..	..	178	22	48.7	..	..	205
	21	α	Cnc	4.3	23	14.1	—0.6	+1.5	84	0	14.2	—1.0	0.0	302
	25	46	B.Vir	6.5	4	58.5	—1.5	0.0	111	6	11.4	—1.5	—0.7	302
OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′.													
Feb.	16	180	B.Tau	6.1	23	17.7	—1.2	+3.8	28	0	14.2	—2.7	—2.2	307
	17	193	B.Tau	6.3	1	59.7	—1.9	—0.7	91	3	21.0	—1.5	—0.7	259
	19	BD+18°1112		6.4	5	22.7	—1.1	—1.2	95	6	30.9	—0.6	—1.6	284
	19	124	H³Ori	5.7	7	8.5	—0.3	—1.7	113	8	5.6	—0.1	—1.1	266
	20	λ	Gem	3.6	9	13.1	—0.3	—0.4	59	9	51.5	+0.6	—2.2	326
	21	BD+14°1850		6.4	6	50.1	—0.5	—2.9	152	7	39.1	—1.5	—0.3	245
	21	α	Cnc	4.3	23	5.5	0.0	+1.4	84	23	59.7	—0.5	+0.3	298
	25	46	B.Vir	6.5	4	38.9	—0.8	—0.6	138	5	42.1	—1.5	+0.8	272
	29	73	B.Sco	6.4	13	18.0	—1.8	—0.9	99	14	36.9	—1.4	—1.2	271
OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′.													
Feb.	1	32	Lib	5.9	11	15.9	—1.6	+2.0	71	12	14.1	—0.7	—1.0	327
	3	166	B.Oph	6.5	12	46.7	..	..	36	13	20.9	..	..	342
	13	171	B.Psc	6.3	4	40.0	—0.3	—2.7	122	5	23.0	—0.3	+1.4	207
	17	193	B.Tau	6.3	0	55.1	—2.2	+0.7	89	2	23.4	—2.2	+1.1	246
	17	δ	Tau	3.9	7	31.1	—0.5	—0.9	82	8	31.5	0.0	—1.4	278
	17	64	Tau	4.8	8	5.2	—0.1	—1.4	104	9	1.6	+0.1	—0.8	257
	19	BD+18°1112		6.4	4	42.7	—2.0	—2.2	131	5	53.1	—2.3	+0.7	242
	19	124	H³Ori	5.7	7	9.7	..	..	167	7	38.2	..	..	213
	19	292	B.Ori	6.5	10	10.3	+0.1	—1.6	119	11	0.9	+0.2	—0.8	260
	20	λ	Gem	3.6	9	0.0	—0.8	—1.3	101	10	2.8	—0.4	—1.6	289
	21	30	B.Cnc	6.1	4	43.6	—2.1	+0.8	86	5	59.4	—1.8	—1.4	306
	24	359	B.Leo	6.3	12	59.3	—0.6	—2.0	137	13	54.3	—0.6	—1.1	267
	25	46	B.Vir	6.5	4	40.2	..	..	190	4	51.3	..	..	212
	27	λ	Vir	4.6	14	27.9	—1.4	—1.5	117	15	37.9	—1.1	—1.2	271
	29	73	B.Sco	6.4	12	21.7	—1.8	—0.4	121	13	44.5	—2.4	+0.1	264
	29	88	B.Sco	6.4	15	30.0	—2.0	—1.6	122	16	40.4	—1.3	—0.4	246

The quantities in the columns *a* and *b* are given for the purpose of making

these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Novae in the Magellanic Clouds: An extensive examination of plates by the Harvard investigators has resulted in the discovery of a third nova in the Magellanic Clouds. In the Andromeda Nebula twenty or more novae, it is estimated, occur each year, but very few have been found either in Messier 33 or the Clouds; the survey of 2500 known variable stars in the Clouds has revealed to date only three novae—one in the Small Cloud and two in the Large Cloud. Their occurrence in these systems thus appears to be exceedingly rare.

In absolute magnitude the three novae are comparable to those found in our galactic system. The light curve of the new Large Cloud nova is typical of such objects, in that it rose rapidly to maximum, whereas the rise of the nova in the Small Cloud, VZ Tucanae, was slow and the descent rapid. The curve for RY Doradus, the other Large Cloud nova, is too fragmentary for determination of rapidity of rise or fall.

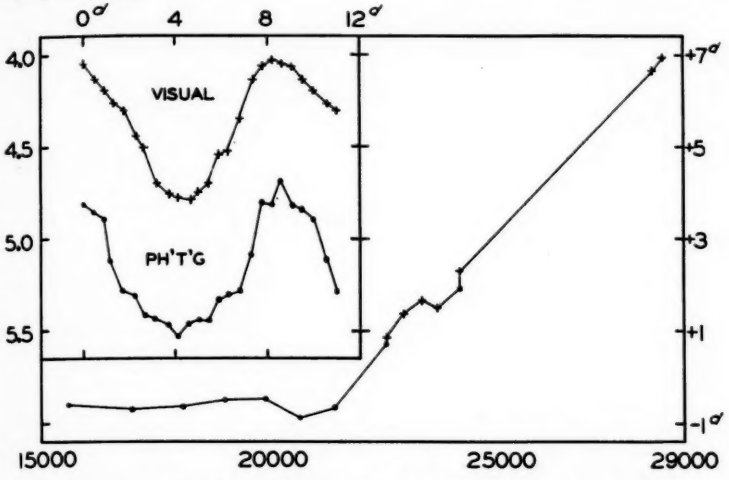
Period Changes in κ Pavonis: The contribution of some 550 visual observations of κ Pavonis by Mr. A. W. J. Cousins of Durban, South Africa, made during the years 1920-1925 and 1936-1937, offer excellent material for deriving the period of this star, one of the few southern, bright classical Cepheid variables. His derived period of 9.097 days fits these observations quite satisfactorily, but when it is compared with others already published, a marked deviation is found to exist. A. W. L. Roberts gave periods of 9.1014 and 9.09155 days; R. Müller, a value of 9.106 days; and Shapley, 9.08799 days.*

When the visual observations of Cousins were reduced on the basis of a period of 9.08799 days, which well satisfied the earlier photographic observations, it was found that after the year 1915 there had been an abrupt change in period; that is, the period was 13 minutes longer than during the years 1899 to 1915, or 9.09701 days. This change in period was in fact indicated to some extent, but not noted, in the Harvard photographic observations, which covered the years 1899-1926.

The period-change is illustrated in the accompanying figure, computed on the basis of 9.09799 days, dots representing the photographic observations and crosses

*The period, through a typographical error, is given as 9.08979 in Table II of Harvard Reprint 67 (1930), but the correct value was used in computing the phases in Table IV.)

the visual. Straight lines drawn through the plotted points well represent the change in period.



MEAN LIGHT CURVES AND O–C CURVE OF K PAVONIS

It would be helpful in discussing the period-changes prior to 1900—if such occurred—to have available the original observations made by Roberts and Williams, and those at Cordoba; without these data it is impossible to derive an accurate period covering the very early years. There appears to be too much uncertainty in the published times of maximum and minimum.

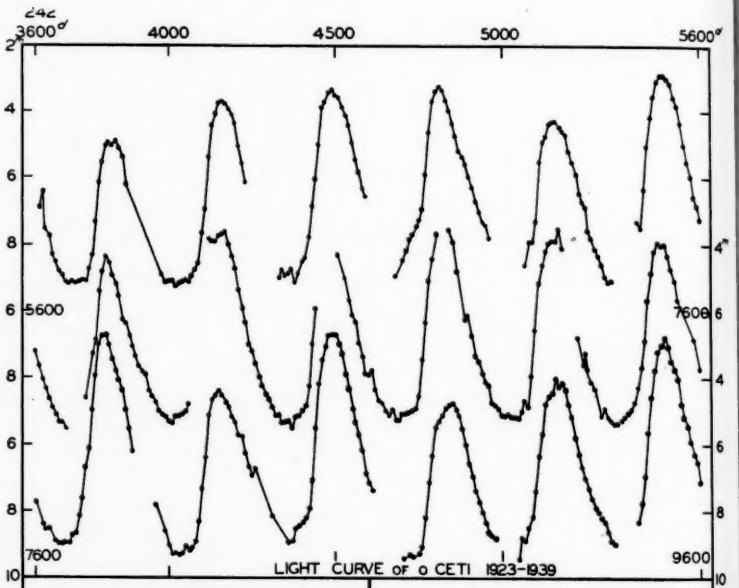
Just what the full significance of such a change in period may be, is difficult to say. No other Cepheid is known to have undergone such a large and abrupt change, and the star requires careful attention in this respect during the coming years.

A comparison of the mean light curves derived from the visual and photographic observations is of interest. The comparison is made in the accompanying figure, where the visual observations are indicated by crosses, the photographic by dots. There is a systematic color-correction difference between the two curves, the photographic being three-quarters of a magnitude fainter than the visual, although the range in both curves is about the same. The photographic curve has a wider, flatter minimum than the visual, also a sharper and narrower maximum. To what extent this lack of agreement can be attributed to the different methods of observation or magnitude scale values, or to the inherent differences in the visual and photographic portions of the star's light, remains to be determined.

One outcome of this comparison of visual and photographic observations is an appraisal of their relative reliability. The accordance between the two systems seems excellent. Individual light curves derived for different epochs show some dissimilarities in shape of curve, but the dissimilarities seemingly vanish when the several curves of each system are brought into a final curve. The still-stand on the ascending branch of the curve, mentioned by some observers, appears to be unreal when looked for in the final mean curves.

The Recent Light Curve of o Ceti: Probably no other variable star (at least, no long-period variable) has been so completely observed as the first star to be recognized as such, namely, Mira or o Ceti. It is safe to say that, except when o Ceti is near the sun in spring, not one maximum in the past half-century or more has escaped attention, mainly because of the star's great brilliance at maximum and also because its primacy as a variable has made it of interest, particularly to amateur observers.

The period is so close to 333 days that six maxima occur in every 2000-day interval, so that a plot of the observations in rows of 2000 days each depicts conveniently the regularities and irregularities in the light curve. The observations for the years 1923 to 1939, here plotted and discussed, were made by members of the A.A.V.S.O.



In the table are given the Julian dates of the phases read from the curve, (1) when the star attains magnitude 6.0 on the increase, (2) at maximum, (3) at magnitude 6.0 on the decrease, and (4) at minimum. First differences between these consecutive values indicate the uniformity with which the respective phases are reached. The magnitude at maximum, as read from the curve, is given in the last

column. An examination of these first differences shows that those for maxima have the smallest average deviation, ±7 days, while the largest is derived from the 6.0 magnitude phases on the decreasing side of the curve, namely ±15 days. One may conclude that the regularity of the period is most consistent at maximum phases, although the phase at magnitude 6.0 on the slopes of the curve can be more accurately read off than either the maximum or minimum phases. The best period derived from these particular observations appears to be 333.2 days, in contrast to the value of 331.48 days derived from the data analyzed for the years 1596 to 1932, as published in the Harvard Tercentenary Volume.

J.D. 6.0 I 242	Δ	J.D. Max. 242	Δ	J.D. 6.0 D 242	Δ	J.D. Min. 242	Δ	Mag. Max.
3792	326	3828	334	3870	358	3718	312	4.8
4118	322	4162	329	4228	344	4030	325	3.7
4440	330	4491	323	4572	328	4353	329	3.3
4770	338	4814	344	4900	322	4682	346	3.2
5108	324	5158	330	5222	350	5028*	320	4.3
5432	354	5488	325	5572	287	5348	352	2.8
5786	314	5813	335	5859	366	5700	305	4.3
6100*	338	6148	334	6225	325	6005	350	3.7
6438	337	6482*	336	6550	340	6355	337	4.3*
6775	327	6818	337	6890	322	6692	333	3.2*
7102	336	7155	325	7212	328	7025	324	3.6
7438	322	7480	324	7540	350	7349	323	3.9
7760	352	7804	344	7890	332	7672	344	2.7
8112	327	8148	342	8222	356	8016	349	4.3
8439	355	8490	350	8578	313	8365	343	2.7
8794	324	8840	320	8891	337	8708	315	4.7
9118	321	9160	327	9228	350	9023	337	4.0
9439		9487		9578		9360		2.8

*Extrapolated readings from curves.

A marked irregularity in the height of maxima for this star, as well as for many other long-period variables, has been the subject of considerable interest. A possible correlation has been found in the light curves of o Ceti between the varying observed magnitudes at maximum and the intervals between consecutive attainment of magnitude six on the increase to maximum, as well as the width of maximum at the same 6.0 magnitude point. When the maximum is exceptionally bright, it is preceded by a relatively short cycle between the phases at magnitude 6.0 I; when faint, the cycle is correspondingly longer. Also, for the brighter maxima the width across maximum at magnitude 6.0 is larger than for the fainter maxima. These features are better illustrated in the curves shown below the plotted light curves. Such close correlations do not appear to exist for places other than those at magnitude 6.0 I.

The increase in light following the minimum at J.D. 2424682 is decidedly more retarded than in any similar portion of an individual light curve here shown. It must be recalled that Mira has a companion, often suspected of variability, and at that particular minimum the companion may have been exhibiting this possible characteristic.

A detailed study of the light curves preceding 1923 will be required to substantiate the correlation here mentioned. The rapidity of rise to maximum seems to have little, if any, relation to the magnitude at maximum itself.

Observers and Observations during November, 1939:

Observer	Var.	Est.	Observer	Var.	Est.
Albrecht	17	21	Irland	5	5
Baldwin	96	126	Jones	83	360
Ball, A. R.	37	37	Kearons	58	111
Ball, J.	37	51	Kelly	20	40
Ballhaussen	4	4	de Kock	53	169
Blunck	30	34	Kozawa	8	33
Bouton	59	81	Loreta	189	530
Britzelmayer	4	10	Lovinus	5	5
Brocchi	19	43	Lundquist	31	44
Buckstaff	16	31	Maupomé	37	38
Callum	26	34	McKeon	1	1
Christman	11	11	McPherson	45	74
Cilley	44	100	Meek	39	523
Cousins	30	102	Millard	18	24
Dafter	5	14	Monnig	2	2
Diedrich	14	14	Moore	16	22
Economou	22	25	Palo	22	30
Ensor	35	42	Parker	36	39
Escalante	74	87	Peltier	26	123
Ferguson	1	1	Purdy	11	16
Fernald	88	152	Rosebrugh	20	68
Ford	23	25	de Roy	17	44
Franklin	22	31	Ryder	14	14
Gregory	58	60	Schoenke	12	12
Griffin	20	21	Shafer	7	18
Harris	23	24	Saxon	3	3
Hartmann	182	304	Shultz	3	3
Hassler	1	1	Sill	48	49
Hayner	4	8	Smith, F. P.	31	53
Heckenkamp	5	6	Webb	15	15
Hiett	12	12	Webber	32	32
Hildom	35	80	Whittier	4	4
Holt	96	167	Yamada	7	25
Houghton	54	60	Yamasaki	34	35
Houston	137	603			
Howarth	17	17	Total		5008

December 14, 1939

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Enough reports have arrived for a brief discussion of the Leonid meteors in 1939. We are most indebted to Professor M. L. Braun, Department of Mathematics and Physics of Catawba College, Salisbury, North Carolina, who himself observed on November 14, 15, and 16. He also had 10 of his students observe on these nights, several on each night, and estimated that 80% of all meteors seen were Leonids. Next I should mention Professor P. R. Burch, Department of Biology of State Teachers College, Radford, Virginia, who himself, with 7 students, observed on November 15. Both of these large groups had persons facing different quadrants so the data are rather complete for counts. No plotting was attempted by either. Both Professor Burch and Professor Braun in past years have taken an active interest in the work of the A.M.S. in this eminently practical

way, as well as in reporting fireballs. Last month I mentioned at some length the excellent work done under Professor Donald Faulkner at Stetson University, Deland, Florida, which was planned for meteor height determinations. I am wondering why in the other forty-odd states, heads of science departments in some of the innumerable colleges and universities do not more often encourage their students to engage in meteor work, at least at the time of the two main fall showers. I believe there are many students, interested in science, who would willingly take part and find pleasure as well as benefit in so doing.

Our colleague in Italy, E. Loreta, had bad weather on the whole for the Leonids and reported his disappointment. He plotted part of the meteors seen. R. M. Dole, who observed on five consecutive nights, had the poorest luck on all but November 16 when he observed (and mostly plotted) 71 Leonids. Dole's data are not comparable with those of others because he, as a rule, does not record sporadic meteors. This makes it impossible to derive his rates for the nights in question. However, he made one observation of the greatest importance. On November 16 at 14:08 (according to his report; there is one other which places what may be the same object 6 minutes later) a brilliant Leonid, bright as the full moon, appeared in the N.W., was seen over a course of some 30° and disappeared beyond the horizon. This superb object left a train visible for 43 minutes, after which it disappeared by drifting behind trees, when still bright enough to be seen, though by this time a mere hazy ball of light. I am hoping that duplicate observations of this object can be obtained, for it must have been widely seen over northern New England and eastern Canada. Will not readers of this note make an effort to recover observations on this fireball so that the true height and directions of drift may be determined? We are further fortunate in an observation of a bright meteor made by Loreta on November 8 at 9:22. This was at least —2 magn., and with his field glasses he was able to follow the changes in the train for 190 seconds. Both he and Dole sent me complete drawings of the original meteor paths and subsequent drift of trains. Loreta tried to secure a duplicate observation but was unsuccessful except for one of rather uncertain value, which was not good enough for height determination.

It is most encouraging to find that ships' officers also are reporting more long-enduring trains, so that our data are growing in both number and value. I have been held up by the pressing necessity of preparing for publication our ten years of variable star work with the 18-inch refractor, but as soon as I can get this out of the way, I hope to concentrate again upon the long-enduring train problem, and finish my researches during the coming year. Therefore I again beg of all readers to observe most carefully and send me *at once* full descriptions of any train which lasts as long as one minute, or of any of shorter duration which show the least drift. Prompt reporting often permits me to secure other observations which are not to be had a week or two later, for the newspapers naturally do not wish to print belated requests, when the news interest is dead. I desire my catalogue of these objects to be as complete as possible and this can only be accomplished by coöperation of all persons interested in science.

On the whole, the 1939 Leonids gave a pretty good display, considering how long it has been after their expected maximum. The Virginia observations, made by a large group, indicate good numbers on November 15. This is confirmed by the group in North Carolina, but they have also a good rate for November 16. Dole, however, got almost nothing on November 15, but a high maximum the next night. Stone also had his best rate on November 16. This indicates the great

necessity for having reports from many observers, scattered over the whole country, if we wish to have a true picture of the behavior of any meteor shower. Local conditions, for reasons far from clear to me, seem often to have unexpected importance. I refer here to other factors than mere transparency of the atmosphere. Many of our observers are most careless in not giving the condition of the sky, from which F is determined. Will they not reform?

A new supply of telescopic meteor blanks has been ordered and will be available before this appears. Full supplies of the new and corrected maps by E. A. Halbach and a new edition of blanks are on hand. Hence requests for supplies from our members can be promptly filled. We again take occasion to ask the coöperation of all A.A.V.S.O. members in observing telescopic meteors. It takes practically no extra time to record the relatively few seen during the course of a year. We will gladly furnish the blanks, which have instructions printed on the back, on request, to anyone who has access to a telescope and will use them. Once more we request A.M.S. members to remit their dues in January without forcing us to the useless trouble and expense of mailing bills. The annual report for 1939 will probably appear in the March Meteor Notes. To be included, reports must be in my hands by February 15 *at the latest*. We much desire to stop the nuisance of supplementary reports due to delay in our members sending in what they have done. Please be prompt this time. This request is especially made to our various regional directors who are most of all accountable for these delays. Let us make 1940 one of the most active years in the history of the A.M.S.!

Observer and Station	Date 1939	Began	Ended	Min.	F.	Met.	Rate	*
Braun, M. L., Salisbury, N. C.	Nov. 14	10:25	12:25	120		7	3.5	(1)
	15	16:45	18:00	75		22	17.6	(2)
	16	16:10	17:40	90		32	21.3	(2)
Van Poole, T., Salisbury, N. C.	14	12:30	14:30	90		17	11.3	(1)
Armstrong, C., Salisbury, N. C.	14	10:35	11:30	55		3	2.8	(3)
Rector, Miss L., Salisbury, N. C.	14	12:00	14:00	90		17	11.3	(3)
Poole, J. W., Salisbury, N. C.	14	15:45	17:40	105		9	5.1	(4)
Quick, M., Salisbury, N. C.	14	14:00	16:00	120		17	8.5	(4)
Safrit, Miss E., Salisbury, N. C.	14	12:08	14:00	112		10	5.4	(5)
Yoder, Miss S. E., Salisbury, N. C.	14	12:00	14:00	120		26	13.0	(6)
Whitener, W., Salisbury, N. C.	14	11:57	14:00	123		19	9.3	(5)
	15	11:15	12:04	49		14	17.1	(5)
	16	12:30	14:30	90		14	9.3	(1)
Middleton, D., Salisbury, N. C.	15	14:05	16:00	115		22	11.5	(7)
	16	10:00	12:00	105		5	2.9	(3)
Hardin, C., Salisbury, N. C.	14	14:00	16:00	120		29	14.5	(8)
	15	14:30	16:00	90		21	14.0	(8)
Burch, P. R., Draper Mt., Va.	15	13:45	15:15	65	1.0	14	12.9	(8)
Lawhorn, Miss M., Draper Mt.	15	13:45	15:15	65	1.0	34	31.5	
Montgomery, Miss G., Draper Mt.	15	13:45	15:15	65	1.0	25	23.2	
Poff, Miss H., Draper Mt.	15	13:45	15:15	65	1.0	27	25.0	
Yeatts, Miss E., Draper Mt.	15	13:45	15:15	65	1.0	32	29.7	
Bussey, Miss G., Draper Mt.	15	13:45	15:15	65	1.0	21	19.5	
Graham, Miss H., Draper Mt.	15	13:45	15:15	65	1.0	15	13.9	
McCraw, Miss M., Draper Mt.	15	13:45	15:15	65	1.0	29	26.9	
Loreta, S., Bologna, Italy	8	10:00	10:55	50		11	13.3	
	13	15:00	15:55	50		13	15.7	(9)
	14	10:00	10:55	50		7	8.5	(10)
	17	15:00	15:55	50		18	21.8	(11)
	18	10:00	10:55	50		7	8.5	(10)
Laerman, J., Baltimore, Md.	14	12:15	13:15	60		0	0.0	
	15	13:15	14:15	60		7	7.0	
	16	14:45	15:45	60		18	18.0	(12)
	17	13:45	14:45	60		0	0.0	

Observer and Station	Date 1939	Began	Ended	Min.	F.	Met.	Rate	*
Hoag, A. A., Barrington, R. I....	16	13:	15:	120	0.7	20	10.0	
Hoag, A. A., Providence, R. I....	17	12:39	14:34	96	1.0	32	20.0	(13)
Bloemendal, G. W., Oak Park, Ill.	13	12:30	15:30	90		3	2.0	
	14	15:	16:	60		0	0.0	
Stone, W. R., Santa Barbara, Calif.	14	11:30	15:	210		10	2.9	
	15	13:	16:	180		4	1.3	
	16	13:	16:	180		24	8.0	
Avery, V., Banks, North Dakota..	3	8:07	11:20	175	1.0	18	6.5	
	4	7:59	9:59	120	1.0	19	9.5	
	5	8:03	10:31	148	1.0	19	7.7	
	11	7:45	8:55	70	1.0	12	10.3	
Dole, R. M., Cape Elizabeth, Me..	13	14:	16:	120		0		
	14	14:	16:	120		2		
	15	14:	16:	120	1.0	4		(14)
	16	14:00	18:15	255	1.0	71		(15)
	17	14:00	16:00	120		3		(15)

NOTES: (1) observing to NW. (2) Observing to Leo. (3) Observing to zenith. (4) Observing to S. (5) Observing to zenith and W. (6) Observing to zenith and E. (7) Observing to N. (8) Observing to E. (9) 4 Leonids. (10) 1 Leonid. (11) 6 Leonids. (12) 5 brilliant. (13) 12 Leonids. (14) All Leonids. (15) No Leonids.

Flower Observatory of the University of Pennsylvania,
Upper Darby, Pennsylvania, 1939 December 11

The Orbits of Two Meteors

(July 25, 1929, and January 24, 1934)

By C. C. WYLIE

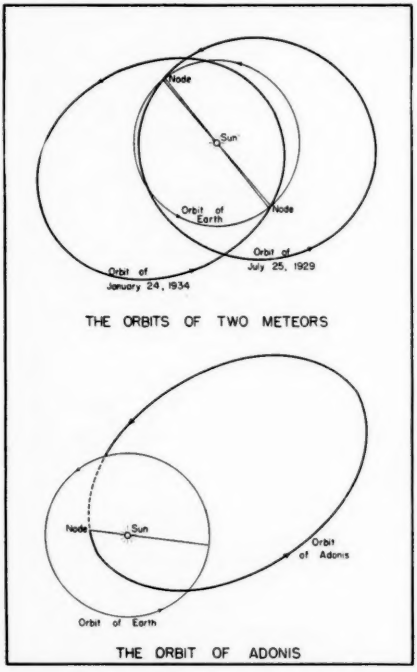
The meteor of July 25, 1929, which fell in northern Illinois at 9:46 P.M., lighted up nearly a million square miles of territory. It was noticed by many from lighted rooms, and was quite bright enough to have been detonating. A thunderstorm was in progress, however, over the area where detonations would have been heard, and none were noticed. The geocentric radiant and velocity are taken from Contribution Number 6 of the University of Iowa Observatory, pages 191-192. The accuracy of the calculated path is indicated by the small probable errors given on page 197 of that Contribution.

The meteor of January 24, 1934, was a spectacular detonating meteor which fell in eastern Iowa at 11:00 P.M. It startled one man so that he almost drove his car into the ditch. One lady thought that the Day of Judgment had arrived. The geocentric radiant and velocity are taken from Contribution Number 6, page 205. The accuracy of the calculated path of this meteor is indicated by the probable errors on pages 207-208 of Contribution Number 6.

Both geocentric radiants are south of the ecliptic, showing that the meteors fell at the ascending nodes of their orbits. The orbits were computed by the method given in Contribution Number 9 of the University of Iowa Observatory, or POPULAR ASTRONOMY, October, November, and December, 1939. The calculations have been carried through independently by the author and Mr. J. W. Kitchens, research assistant in astronomy. The following are the elements of the orbits.

	July 25, 1929	Jan. 24, 1934
a	1.43	1.54
e	0.35	0.55
ω	50°.3	81°.1
☊	302°.7	124°.6
i	1°.9	7°.0
P	1.70 yr.	1.92 yr.

The drawing shows the two orbits projected on the plane of the earth's orbit. It also shows the orbit of Adonis in the same way. These projected orbits can be



compared with those shown in Contribution Number 9, or POPULAR ASTRONOMY, December, 1939.

In closing let us mention the work of H. A. Newton[1] on the orbits of meteor dropping meteorites. From a study of the radiants, the great majority quite approximate, Newton concluded that nearly all these bright meteors had been moving in direct orbits, with periods, inclinations and eccentricities smaller than for the average comet. The orbits recently computed at Harvard from photographic work, and at Iowa from measurements made at personal interviews, agree in showing that Newton's conclusion for meteors dropping meteorites can be extended to the brighter meteors in general.

University of Iowa, December 13, 1939

[1] *American Journal of Science*, Series 3, Vol. 36, pp. 1-13, 1888.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California, Los Angeles

President of the Society: H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver

Secretary of the Society: ROBERT W. WEBB, Department of Geology, University of California, Los Angeles

Philippine Tektites and the Tektite Problem in General*

By H. OTLEY BEYER,
Department of Anthropology, University of the Philippines, Manila

ABSTRACT

Great showers of tektites fell upon certain parts of the earth at widely separated geologic periods. The four major geologic groups are:

(1) The Ivory-Coast deposit, believed to be Mesozoic;
(2) The Moldavites, or European, from the Helvetian strata of mid-Miocene;
(3) The Indo-malaysianites, undoubtedly mid-Pleistocene; and
(4) The Australites, believed to be post-Pleistocene or recent.

The typical forms—spheroids, disks, or oval, cylindrical, dumb-bell-shaped, and pointed, drop-shaped bodies—suggest natural shapes assumed by molten glass revolving in the atmosphere or a similar gaseous medium. The Australites show a partial re-fusing of the original glass sphere and backward flow, producing a peculiar button-like appearance.

Group three, which includes the Philippine tektites, may be divided into four major subgroups: (1) Indochinites; (2) Rizalites; (3) Billitonites and Malaysianites; and (4) Java Tektites. The characteristics *etc.* of these bodies are discussed in some detail.

Of the various theories of the origin of tektites, three are still worthy of consideration. These are: (1) the theory of volcanic or other earthly origin; (2) the burning, light-metal meteorite theory; and (3) the meteorite explosion-crater theory. An astronomical theory of tektites, proposed by Dr. W. Carl Rufus, is summarized and briefly criticized, *pro* and *con*.

The Philippines present a unique opportunity for the study of the richest known deposit of tektites in their natural environment. The only local students of the problem are the writer and Dr. Miguel Selga, S.J., joined recently by Mr. J. Van Eck. To stimulate local interest, the present outline was presented to the Philippine National Research Council.

One of several things for which the Philippines are remarkable is the presence in the Islands of the world's largest known deposit of tektites. The term *tektite*

*[Prepared originally for presentation at the Sixth Pacific Science Congress in the San Francisco Bay region, California, July and August, 1939, to accompany the following paper by Dr. W. C. Rufus on "An Astronomical Theory of Tektites." As no other papers of a meteoritical nature were received by the Congress, its Secretary, Dr. R. E. Clausen, transferred these communications to the Society for Research on Meteorites. With the authors' permission, both papers were read at the Seventh Annual Meeting of the Society in Columbus, Ohio, December, 1939, and are here included in the *C.S.R.M.*—EDITOR.]

was adopted in 1900 by Professor Franz E. Suess of Vienna as a general name for a curious group of natural glasses which have come to be widely regarded as of cosmic or extra-earthly origin. In recent times, it has become apparent that these bodies did not fall singly or sporadically, but that great showers of them fell upon certain parts of the earth at widely separated geologic periods. A small deposit has been found in the Ivory-Coast region of West Africa that is believed to date as far back as Mesozoic times; the Moldavites, or European tektites, date from the Helvetian strata of the mid-Miocene; the whole group of Far Eastern tektites, or Indo-malaysianites, are undoubtedly mid-Pleistocene; while the Australites, or tektites of Australia and Tasmania, are believed to be post-Pleistocene or recent. These four major geologic groups of tektites all differ from one another to some extent in physical appearance, chemical composition, and specific gravity, but all possess certain common differences from other earthly rocks which have led them to be classed together as genuine tektites, of unknown but probably cosmic origin.

Most if not all true tektites appear to have been originally of the natural shapes that would be assumed by molten glass revolving in the atmosphere or any similar gaseous medium, *i.e.*, spheroids, disks, or oval, cylindrical, dumb-bell-shaped, and pointed, drop-shaped bodies, some later broken or exploded into fragments of various sizes. This fact, together with their anomalous chemical composition, and the further fact of their being found frequently in wholly non-volcanic regions, have been the chief reasons for adopting the cosmic hypothesis in seeking a reasonable explanation of their origin. The Australite group of tektites adds still further probability to the cosmic theory by showing a partial re-fusing of the original glass sphere, a part of which has flowed backward and solidified into a more or less flattened ring or band, giving to the whole specimen a peculiar button-like appearance, in the typical forms. In many other cases, the re-fused material has been completely swept away in flight, leaving only a small sharp-edged or lens-shaped remnant of the original tektite sphere.

The Philippine tektites all belong to the general Indo-malaysianite group, of mid-Pleistocene origin; this group contains also the tektites found in Indo-China, Borneo, and the Island of Java. While presenting great uniformity in composition, and in color, specific gravity, and other properties of the glass itself, the Indo-malaysianites of different geographic areas present certain characteristic differences in shape, surface markings, flow-lines, and the degree of viscosity of the original material, which have led to their being divided into four major and several minor subgroups of more or less distinctive and well-defined character. The four major subgroups are:

(1) *Indochinites* (originally most viscous, with stretched-bubble sections, and with both straight and curved pointed drops, and irregular fragments as the most characteristic forms, spheroids being rare);
(2) *Rizalites* (pitted spheroids, ovals, and cylindrical forms being most characteristic, showing intermediate viscosity);
(3) *Billitonites* and *Malaysianites* (with deeply-etched spheroids, cylinders, and irregular pieces, showing worm-track grooves and navels as the characteristic forms; medium viscosity); and
(4) *Java Tektites* (least viscous?, with highly complicated flow-lines mildly but clearly etched out on relatively smooth surfaces, and with spheroidal and irregular or fragmentary forms as the most characteristic).

The most typical *Indochinite* specimens occur in South China and northern and central Indo-China, although they are found also, sparsely, in Luzon (particu-

larly in the Rizal-Bulakan area, where they are mixed with much larger numbers of Rizalites and a few Billitonite and Malaysianite types).

The most typical *Rizalites* occur only in Luzon, although a few similar, pitted specimens are known from Borneo and Java.

The *Billitonite* and *Malaysianite* types, although least in number, cover the greatest area, being found in parts of southwestern Luzon, the Island of Busuanga in the west-central Philippines, Borneo, the Natuna archipelago, southern Indo-China (especially Cambodia), the Malay Peninsula, and the Island of Billiton. The original Billitonites (first found in the tin mines of Billiton Island) show characteristic worm-track grooves and navels, with relatively smooth surfaces between such markings, while the true Malaysianites tend to show irregular and heavily-etched surfaces with the irregular pits and other markings often running together more or less continuously, as seen most typically in many Cambodian and Busuanga tektites.

The most typical *Java tektites* are found only in central Java, but a few very similar specimens occur in the Philippines (particularly in the Santa Mesa district of Rizal Province).

The largest known whole tektites occur in southeastern Luzon, in the Paracale district of the Bikol Peninsula, while those of Indo-China rank next, and the Malaysianites probably third. The great Bikol tektites may be truly called "super-sized," since *most* of them are large, and small specimens comparatively scarce. The largest found so far weighs 1070 g., and is an almost perfect sphere a little over 4 inches in diameter, but more than a hundred Bikol specimens running from 200 to 700 g. each have so far been found. The largest recorded whole Indo-China specimen is from Cambodia, and weighs 630 g., while the largest known Malaysianite is believed to have come from Pahang and weighs 464 g. Only a few other specimens weighing 300 g. or more are known, all of them having come from the Indo-malaysianite region, most of them being from Indo-China and the Philippines, with one each from Java and the Malay Peninsula. The average for this region, however, is between only 15 and 20 g. The largest Australite has the exceptional weight of 218 g., since the Australites are the smallest of all tektites, averaging only about 1 g. each or less. Tektites from other regions are intermediate, but no recorded specimen reaches 150 g. in weight.

However, what was originally probably the most gigantic of all tektites is again recorded from Indo-China. This is the famous specimen of Lower Laos, of which several thousand irregular fragments have so far been gathered within a relatively small area. The largest piece weighs more than 3 kg., while many of the smaller ones weigh only a few grams each. The evidence to date seems to indicate that all of these pieces are parts of a single huge tektite, perhaps half a meter in diameter, and weighing nearly 100 kg. One of the most interesting things about these finds is that no other small whole tektites have been found anywhere near the same region; this fact lends force to the cosmic theory, since any shower of smaller bodies accompanying this great cosmic bomb would have tended to fall far behind in the course of its flight through the earth's atmosphere.

This brings us back again to the various theories accounting for the origin of the tektite glass itself. Many such theories have been propounded in the past, but most of them have been demolished by the extensive and often bitter criticism to which they have been subjected. A few theories, however, have withstood much critical discussion and are still worthy of serious consideration, although no single theory has yet received universal or wide acceptance among a majority of those

interested in the major tektite problem and its solution. I shall conclude this paper by summarizing, first, the essential features of three views that are still being seriously considered and shall then present a new hypothesis that has recently been worked out on the basis of Philippine material and that seems to present certain features which will doubtless provoke much interesting discussion and may even add a new chapter to tektite history.

First, although no one has yet ever been able to present acceptable proof of the volcanic or other earthly origin of the tektite glasses, there is still an appreciable number of students of this question who believe that such an earthly origin will some day be demonstrated; therefore, this possibility should not be disregarded, although majority opinion is today decidedly against it.

Second, the view known as "the burning light-metal meteorite theory" (a theory developed in its various stages by Goldschmidt, Michel, Lacroix, and Suess) is still regarded by many capable investigators as the most acceptable explanation of tektite origin yet presented. In brief, this view is based on the generally accepted idea that the great seasonal meteoric showers which so frequently visit the earth's atmosphere, and are mostly wholly consumed in the upper air, consist in the main of the light metallic elements which oxidize at normal or relatively low temperatures. It is generally believed that a considerable amount of finely divided silica or siliceous matter is shed from such showers, probably reaching the earth usually as a fine powder or dust. This tektite theory presupposes that the earth has occasionally passed through abnormally thick clouds of such matter—such as, *e.g.,* those which are commonly believed to form the tails of some comets *etc.*—and that at such times the quantity of siliceous matter shed would be sufficient to form sizable globules of liquid glass, falling to the earth in solidified form as a tektite shower. (The principal objection to this view, in the mind of the present writer, is the difficulty of explaining the secondary re-fusing of the Australites and the absence of such secondary forms in the Indo-malaysianites, since the glass of both types is of practically identical composition, color, and specific gravity. Van der Veen, however, has suggested that this difference was due to the more fluid nature of the Australite glass, while the Indo-malaysianites were more viscous. The increasing viscosity of the Indo-malaysianite glass, from Java northwestward to South China, seems to support Van der Veen's view.)

Third, Spencer's "meteorite explosion-crater" theory, while regarded as unacceptable by a majority of tektite students, is, in my opinion, still to be considered as a possible clue to the origin of many important varieties of pseudo-tektites *etc.,* such as the silica glasses, Darwin glass, the Americanites, the Philippine psuedo-Americanites of Santa Mesa and vicinity, the Claveria psuedo-tektites, and possibly even the European Moldavites. The essentials of this view are, briefly: Quantities of silica glass of several types have been found around such great known meteorite craters as those of Arizona, Wabar, Henbury, *etc.,* and are believed to have been produced by the fusing of earthly rocks and sands by the terrific heat resulting from the explosive impact of the huge meteorites which produced such craters. An explosion great enough to produce a crater a mile or more in diameter would doubtless throw molten silica and other fused material a vast distance into the air, and such material would tend to assume the geometric forms common to glass drops, hardening as it fell back toward the earth. At the time of first propounding this view, in 1933, Spencer felt that the origin of tektites might be thus explained, but in his more recent writing he admits the difficulty of explaining the widespread Australites and Indo-malaysianites on such grounds. The chief argument in favor

of this view of tektite origin is that the composition of tektites approaches that of some earthly clays, but one would need to presuppose temperatures much higher and craters much vaster than any yet known on the earth. (However, we must await more detailed study of the great lunar craters, now coming to be regarded as mainly meteoritic in origin and consider also the possibility that such great craters may have been destroyed or largely covered up by erosion and vegetational growth on the earth.)

The present writer has expressed no personal opinion in favor of any of these theories of tektite origin, but has attempted merely to point out from time to time some of the arguments against or in favor of each of the views. The same attitude will be preserved as regards the new Rufus hypothesis presented herewith.

An Astronomical Theory of Tektites: Under this title Professor W. Carl Rufus, of the Observatory and Astronomical Department of the University of Michigan, has presented to the writer a new explanation for the origin of tektites which is published in the following paper. For the present, I wish only, then, briefly to summarize the essentials of his theory here, and to advance a few short arguments for and against it. The essentials of the theory follow:

> The small natural-glass bodies known as tektites were originally derived in major part from the glassy basalt, or tachylyte, which forms the deeper crustal layer of the earth, exposed chiefly on the floor of the Pacific basin, at the time of the fissional separation of the moon. Furthermore, the earthly tektites represent only a small section of the vast swarms of tiny satellites which remained revolving about the earth within the Roche limit and particularly that section of the satellites having a revolutional period closely coinciding with the period of the earth's rotation. Such swarms would have remained approximately above the Pacific basin, but would have gradually fallen behind and tended to be drawn to the earth on account of perturbations resulting from the gradual retardation of the moon. Cumulative perturbations and other related factors have caused swarms of these bodies to come down to the earth at widely separated geologic periods in the earth's history, such falls having been particularly extensive along a great-circle route crossing the western edge of the Pacific basin. This condition would account for the great quantity and wide distribution of the Indo-malaysian tektites especially, which are of almost identical chemical composition, while other showers of tektites came at different geologic periods and varied somewhat in composition and physical appearance.

While final critical appraisal of the theory must come from others better grounded in astronomical and geophysical knowledge than the present writer, there are certain implications of this new hypothesis that may well be pointed out. First, negatively, the well-known chemical differences between the true tektites and known earthly rocks have not yet been satisfactorily accounted for. It is true, perhaps, that there are very few analyses of deep-seated glassy basalts available in our literature, and that this fact might account for the principal differences observed between the tektite chemical pattern and that of the more widely known surface rocks (either plutonic or volcanic). In particular, the dominance of potash over soda in the tektites is outstanding, and is accompanied usually by a predominance of ferrous oxide. This condition is just the opposite of that of most known earthly rocks and glasses, and it is obvious that further evidence is needed here.

It should be noted, however, that the foregoing objection applies with equal force to all other proposed tektite theories, except the generalized cosmic hypothesis. On the other hand, the Rufus theory explains or lends important support to a number of other views hitherto regarded as not altogether acceptable in their en-

tirety; *e.g.*, Fenner's views as to the origin of the secondary forms of the Australites fit in very well with the Rufus theory; in fact, the Australites furnish probably the best support for the new theory, although they almost certainly represent a different shower from that which gave us the Indo-malaysian tektites. The larger and heavier Indo-malaysian tektites would have been drawn down at an earlier period than the smaller and lighter Australites, although the glassy substance of which both are formed is of almost identical chemical composition.

Past experience has shown that it is easier to demolish tektite theories than to find substantial support for any one of them. Professor Rufus has thus been rightly cautious in presenting his new explanation, and in welcoming expected criticism and discussion. It is hoped that constructive criticism by qualified contemporaries may soon demonstrate whether or not this latest explanation of tektite origin can stand the test and take its place among the few most acceptable theories accounting for these strange bodies.

Position of the Philippines in Relation to Tektite Studies: Up to last year, the present writer and Dr. Siguel Selga, S.J., of the Weather Bureau, were the only local students to take a serious interest in tektite studies, but, since the middle of 1938, Mr. J. Van Eck, of the Marsman staff in Paracale, has been making some very interesting observations on the physical history and characteristics of the Bikol tektites. A monograph by the writer, covering the results of some twelve years' active study and collecting of Philippine tektites, since the first specimen was found in 1926 in a Rizal Province archeological site, will be ready shortly for publication. However, in view of the unique opportunity that the Philippines present for the study of the richest known deposits of tektites in their natural environment, it is to be hoped that other local scientists may soon take a greater interest in this subject; and it is with the hope of stimulating such interest that I am presenting the present outline of the subject at this meeting and to the Philippine National Research Council.

References

Lists of the most important tektite literature, containing the full citations of the principal papers by Suess, Verbeek, Van der Veen, Summers, Michel, Lacroix, Spencer, Fenner, von Koenigswald, and the writer, together with important chronological items by Streich, Walcott, Twelvetrees, Krause, Dunn, Grant, Goldschmidt, Easton, Escher, Paneth, David, deBoer, Selga, Martin, Janoschek, Koomans, Öpik, La Paz, Kašpar, Heide, and others, as referred to in the Beyer and Rufus papers, will be found under the following titles:

(1) Suess, Franz E.: "Die Herkunft der Moldavite und verwandter Gläser," *Jahrb. d. k. k. Geol. Reichsanstalt,* **50**, 193-382, 8 pls., 60 text figs., and bibl. of 55 titles, 1900.

(2) Suess, Franz E.: "Rückschau und Neueres über die Tektitfrage," *Mitt. d. Geol. Gesellschaft Wien,* **7**, 51-121, 3 pls. and new bibl., 1901-14.

(3) Lacroix, A.: "Les Tectites de l'Indochine," *Arch. Mus. Hist. Nat.,* 6th Ser., **8**, 193-236, 12 pls., 43 text figs., and bibl. of 32 titles, Paris, 1932.

(4) Fenner, Charles: "Australites" (Pt. I, 1934; Pt. II, 1935; Pt. III, 1938), *Trans. Roy. Soc. South Australia,* **58**, **59**, and **62**, 8 pls., many text figs., and bibl. of 125 titles (in Pt. III).

(5) Beyer, H. Otley: "A Bibliography of Tektites," listing 450 titles, with brief abstracts and critical notes, Manila, 1939 (in press).

July 21, 1939

An Astronomical Theory of Tektites*

By W. Carl Rufus,
Observatory, University of Michigan, Ann Arbor

Abstract

It is supposed that the small, natural-glass bodies known as tektites were originally derived in major part from the glassy basalt, or tachylyte, which forms the deeper crustal layer of the earth, exposed chiefly on the floor of the Pacific basin, at the time of the fissional separation of the moon; furthermore, that the earthly tektites represent only a small section of the vast swarms of tiny satellites which remained revolving about the earth within the Roche limit, and particularly that section of the satellites having a revolutional period closely coinciding with the period of the earth's rotation. Such swarms would have remained approximately above the Pacific basin, but would have gradually fallen behind and tended to be drawn to the earth, on account of perturbations resulting from the gradual retardation of the moon. Cumulative perturbations and other related factors have caused swarms of these bodies to come down to the earth at widely separated geologic periods in the earth's history, such falls having been particularly extensive along a great-circle route crossing the western edge of the Pacific basin. This circumstance would account for the great quantity and wide distribution of the Indo-malaysian tektites especially, which are of almost identical chemical composition, while other showers of tektites came at different geologic periods and varied somewhat in composition and physical appearance.

The purpose of this communication is to outline briefly an astronomical theory of the origin of tektites, which is presented "with all the distrust that everything not a result of observation or of calculation ought to inspire"! By its very nature, the problem lies beyond the scope of observation and no direct method of attack by mathematical analysis seems possible.

The astronomical theory here proposed refers to showers of small satellites of the earth. It is based on the assumption that some of the matter separated from the earth at the time of the origin of the moon by fission[1] did not immediately fall back to the earth or follow the moon, but continued to revolve about the earth for some time within the Roche limit, *i.e.*, the distance from a planet's center within which a satellite cannot remain without danger of disruption. The Roche limit is about 2.44 times the radius of the planet. It is interesting to note in this connection that Saturn's rings, composed of discrete particles, are within this distance and its nearest satellite, Mimas, lies safely outside.

According to the fission theory, the action of tides raised by the sun in the primitive earth produced an elongated or pear-shaped form of that body. Separation was preceded by a figure of equilibrium consisting of two elongated masses joined by a narrow neck. This state was very unstable and the time of rupture was followed by a period of great turbulence before order was restored in the formation of a satellite. The period of the earth's rotation at that time was about 4^h8. Tidal friction has resulted in decreasing the speed of the earth's rotation (lengthening the day) and by a transfer of angular momentum to the moon, its distance and period of revolution (the month) have increased.

*Read at the Seventh Annual Meeting, Columbus, Ohio, December, 1939. [See the footnote to the title of the preceding paper by Professor H. O. Beyer.]

[1] We here assume a general knowledge of the fission theory of the origin of the moon as advocated by Sir George Darwin and others.

Many fragments produced at the time of rupture were undoubtedly captured within a comparatively brief time by the earth and the moon. We may assume, however, that some of the fragments had initial conditions that produced orbital motion around the earth with a period equal to the earth's period of rotation and in the same general direction, *i.e.*, eastward. For a period of revolution of 4^{h}8, the semi-major axis of the orbit would be about 9,000 miles, which is well within the Roche limit, even for the present size of the earth. Harold Jeffreys concludes that the earth has contracted about 1,000 km. since fission; so the Roche limit was greater then than now.

The condition of the primitive earth, whether gaseous, liquid, or solid, is not definitely known, but it is thought that the moon was formed about the time solidification began and that that process was completed within 10,000 years, which is a very small fraction of the age of the moon, estimated to be of the order of 4×10^9 years. Jeffreys[2] suggests that "The place where the moon emerged gave the largest ocean floor; the Pacific Ocean is thus regarded as the scar left when the moon was formed." During solidification of the earth, the upper layer, chiefly granite (about six miles thick), and the next layer, chiefly basalt (somewhat thicker), were laid down and the ocean water was extruded. The Pacific basin contains little granitic rock, but its islands, *e.g.*, the Hawaiian, and its floor have much basaltic rock. It seems very probable that the mass of the moon with its mean density very similar to that of the earth's upper crustal layer, stripped the Pacific area of its granite at the time of fission and probably lifted some of the material of the basaltic layer. The glassy basalt or tachylyte, being deepest, was the last to leave the earth and would therefore constitute the material which formed the detached fragments. General similarity of the composition of tektites and glassy basalt, including a high percentage of silicon, is thus explained.

The fragments revolving about the earth within the Roche limit then became swarms of discrete particles, including some with periods coinciding with that of the earth's rotation. If the periods exactly coincided, the swarms would remain directly above the area from which the fragments escaped. It is interesting to note a well-known principle in celestial mechanics that applies at this point. Considering the fragments as separate satellites of the earth, we find that they would return in their orbits to the point at which they were formed. To simplify the problem, we may disregard the fate of particles with periods greater or less than one day, which may have been captured at a very early period or been entirely lost. The swarms with periods of one day with initial conditions rightly adjusted would remain over the Pacific at a height depending on the point of rupture, possibly much less than 9,000 miles. Perturbations by the moon, slowly falling behind, would tend to decrease the speed of the particles as the rotation of the earth also decreased. Gradually drawn toward the earth these particles would settle into the atmosphere and fall with speeds sufficient to produce the typical forms, characteristic physical features, and original surface markings of the tektites. The velocity, however, would not be the typical parabolic velocity of meteorites, about twenty-five miles per second, which is so high that this mechanical energy, changed into heat, plus friction in the atmosphere, would cause the small ones to disappear, permitting only the larger masses to reach the surface of the earth.

Distribution, in general near the western edge of the Pacific basin, Australia, the Philippines and other islands, Indo-China, and other places on the mainland, may be accounted for by a slight decrease in velocity, due to increasing resistance

[2] *The Earth*, 2nd Ed., p. 300, 1929.

of the atmosphere at lower levels. The preponderance of tektites in this region seems much more significant than the lesser falls on other parts of the earth. The other showers, however, may readily be accounted for. The David-de-Boer great circle of distribution and the Lacroix-Spncer great circle may be considered to lie directly below the orbits of the chief swarms of satellites. The mutual inclination of these orbits and their inclination to the plane of the earth's equator should present no special difficulty. The large inclination of the orbit of the moon to the earth's equator ($23\frac{1}{2}° \pm 5°$) indicates the sun's influence on the initial conditions and the effect of subsequent action. The orbits of the fragments would be influenced by the combined effect of sun and moon. Falls of tektites farther westward than the west shore of the Pacific, following these two great circles or other possible orbits, represent swarms more retarded in velocity before they finally reached the surface.

The fragments of silica glass larger than the tektites and the meteoritic craters of very early origin, possibly related problems, may readily be considered within the scope of the present theory without separate treatment. Swarms of tektites differing somewhat in mass, silica content, color, form, and other characteristics, would naturally be expected. Difference in the geological periods of the falls may be accounted for by the length of time required for cumulative perturbations, resistance at very high atmospheric levels, and other factors, acting in conjunction with the earth's gravitational attraction, to bring the separate swarms following different orbits down to various parts of the surface.

Although details of the theory cannot be deduced with mathematical precision, it seems to account for the chief facts regarding tektites in a satisfactory way. A large number of articles on the subject have been studied, but we have not found a pertinent fact that seems to be inconsistent. We are submitting the theory for consideration and criticism.[3]

April, 1939

[3][This paper was originally prepared by Professor Rufus for the Astronomical Society of the Philippines, since his interest in the subject began chiefly during his examination of my large comparative tektite collection and associated literature, in Manila, in 1936, and was continued on the basis of Philippine specimens furnished him for further study. As Professor Rufus requested me to write a brief general review of the tektite question to accompany his paper, and as the subject itself is of interest to several branches of science, it was thought best to present the two papers together at the meeting of the Sixth Pacific Science Congress and also at the July, 1939, meeting of the Philippine National Research Council. The Astronomical Society kindly consented to this arrangement, surrendering its right of priority.—H. O. BEYER, Manila, P. I., July 21, 1939.]

Comet Notes

By G. VAN BIESBROECK

On December 11 the Central Bureau at the Harvard College Observatory asked for confirmation of the presence of a cometary object, which was described as follows:

Dec. 9 at $1^h\ 30^m$ U.T. Magnitude 7.
Right Ascension $21^h\ 20^m$; Declination —2° 5′
Motion southeast.

The observation, under the name of Albaugh, was forwarded by N. Bobrovnikoff

with the remark that this object is not the near-by Messier 2 in Aquarius. Last night I took advantage of a clear sky to check the observation but could not find anything corresponding to the description. I covered the region photographically with a 3-inch wide-angle Ross lens. The only cometary object in this vicinity is COMET FRIEND mentioned last month, but it is now hardly as bright as magnitude 10 and on December 9 it was five degrees away from the position given by Albaugh. Further details will have to be awaited.

Of the many comets under observation last month only two remain visible in these latitudes. The first one is COMET 1939 *n* (FRIEND) which, as foreseen, is fading in brightness while traveling southward. By January 1 the position will be $22^h\ 51^m$, $-19°\ 20'$ and the magnitude about 13. Since last month, while losing in brightness, the comet has at the same time become more diffuse and less condensed in a central nucleus; the round coma covers a fairly large diameter of some 6′ (December 9).

PERIODIC COMET 1939 *g* (BROOKS) is the second one that can yet be followed; it is well situated in the constellation of Cetus but the magnitude is not brighter than 15 (December 8). It is surprising that such a faint object still showed a little tail on that date.

Large instruments may possibly still show the presence of COMET 1939 *h* (RIGOLLET) in the latter part of the night, but it is extremely diffuse.

Williams Bay, Wisconsin, December 12, 1939.

Notes from Amateurs

The Cleveland Astronomical Society

On Friday, December 1, in the Lecture Room at Case School of Applied Science we were privileged to hear D. B. McLaughlin, Ph. D., of the University of Michigan. He spoke to us on "Novae and Supernovae," drawing on his wide knowledge and personal research along this line. He showed many excellent slides to illustrate the lecture. Among the best were those of the gaseous spheres and parts of the spheres during different stages of development. Few of us realized the size and rapid development of this envelope from the central nucleus. Many slides showed the spectra of novae and supernovae and well illustrated how the astronomer can tell whether the part under observation is receding or coming toward the observer, and the rapidity of motion. It was suggested that the amateur, if desirous of discovering a nova might direct his attention to the region of Sagittarius. Naked eye or binoculars are sufficient optical aid.

Dr. Nassau called attention at the meeting that from middle November four bright planets will be present in our evening sky; namely, Venus, Mars, Jupiter, and Saturn. They will remain with us through the winter months. On and about March 1 Mercury will appear between the sun and Venus, thus completing the list of naked-eye planets all visible at one time.

DON H. JOHNSTON.

Euclid Beach Park, Cleveland, Ohio.

General Notes

Wendell Phillips Hoge, laboratory assistant and computer at the Mount Wilson Observatory, died on November 14 at the age of seventy-two years. (*Science,* November 24, 1939)

Dr. S. Alfred Mitchell, director of the Leander McCormick Observatory of the University of Virginia, recently gave an illustrated lecture before the West Virginia Chapter of Sigma Xi, entitled "With an Astronomer to the South Seas." (*Science,* December 1, 1939)

Dr. Richard van der Riet Woolley has been appointed director of the Commonwealth Solar Observatory at Mount Stromlo, Australia. Dr. Woolley was chief assistant at the Royal Observatory, Greenwich, from 1933 to 1937, and since then has been John Couch Adams astronomer in the University of Cambridge. He has been editor of *The Observatory* since 1933. (*Science,* December 8, 1939)

Dr. Robert A. Millikan, chairman of the Executive Council of the California Institute of Technology, who is engaged in a study of cosmic rays on a trip around the world, was in India when last heard from. He will continue his trip to Egypt and plans to return to the United States in February. (*Science,* December 15, 1939)

The Rittenhouse Astronomical Society of Philadelphia held its regular meeting on Friday, November 10, 1939, in the Hall of The Franklin Institute. Dr. H. H. Nininger spoke on the topic, "Our Stone-Pelted Planet."

The Rittenhouse Astronomical Society of Philadelphia held a meeting on Friday, December 8, in the Hall of The Franklin Institute. Dr. Newton Pierce, of the Princeton Observatory, spoke on "Eclipsing Variable Stars."

The Hanna Star Dome

The Hanna Star Dome is a dream come true. For over twenty years Harold L. Madison, Director of The Cleveland Museum of Natural History in Cleveland, Ohio, had looked forward and planned for this project. A gift of Mrs. Paul Moore of Convent, New Jersey, in memory of her father, Mr. Leonard C. Hanna, made it possible. It is for the use of the people of Cleveland and especially the children.

During museum hours, visitors may see the stars just as they will appear between the hours of 9:00 and 11:00 P.M. on the day of their visit.

The dome is of solid copper, 16 feet in diameter and is made in twenty-four sections firmly bolted together. It weighs a ton. The under side is painted a dark blue-black, the top surface is tinned to prevent corrosion. After the dome was set in place, Miss Dorothy A. Treat and Harold L. Madison, Jr., worked for over two months accurately placing 48 different constellations which are to be seen in our Cleveland sky during the year. Each constellation was given as many different settings as there are months in which it is visible in this latitude. The Big Dipper in the northern sky, for example, had to be separately located twelve times, while

Scorpio, low in the southern sky, appears only five times. In all, there are 2844 stars in the dome.

For each star from first to fifth magnitudes, a hole was drilled in the dome. In order, the diameters of the holes are—1st magnitude, 5/64 of an inch; 2nd magnitude, 4/64; 3rd, 3/64; 4th, 2/64; and 5th, 1/64, which last is just pinhole size. On the upper side of the dome the holes are countersunk.

In each countersunk space is cemented a glass brilliant, its point projecting slightly through the hole—blue brilliants for white or blue stars, yellow brilliants for yellow and orange stars and red brilliants for red stars. Over each hole rests a cup-like reflector, 1 inch in diameter. The top of each reflector holds a 6 volt, ¼ ampere radio pilot lamp, rated 1000 hr. life. A brass clip soldered to, but insulated from the dome holds each lamp and its reflector in place. Thus only one wire goes to each lamp, the copper dome itself serving for the other wire. Each lamp bears a number by which it can be located on a chart.

The primary or regular house current of 115 volts, 5 amperes, is transformed to a secondary current of 6 volts, 70 amperes, which is ample to carry the load of 250 stars which is the maximum for any single month. A clock-face switch controls the current. It is so constructed that the secondary is always thrown in before, and released after the primary. Also, only the setting for a single month can possibly be made at one time. There are two miles of wire on the top of the dome running in twelve metal troughs to twelve switch boxes around the base of the dome. In each box are twelve 5-ampere fuses, each carrying the current to not more than 20 lamps on the dome.

The dome room itself is one of the most attractive in the country. Immediately under the dome are shown in colors six spectral classes of stars. Constellations follow below in colors which give place to beautiful paintings of star clusters, spiral nebulae, and comets.

Confusing detail is omitted. Thus it is ideal for learning the constellations and magnitudes of the principal stars. When the room is darkened and the current turned on in the dome a truly striking effect is achieved. The Cleveland Astronomical Society recently held a meeting under the dome.

Euclid Beach Park, Cleveland, Ohio. DON H. JOHNSTON.

Book Reviews

Atlas of Spectra of Nova Herculis 1934, by F. J. M. Stratton and W. H. Manning. (Cambridge University Press, 1939. 25 shillings.)

This publication is entirely unique. Never before have the spectra of one nova been collected from many different observatories for reproduction of a day-to-day record of changes. When it is noted that the authors have brought to a common scale not only prism spectrograms but grating plates as well, one may gain some idea of the difficulty of the undertaking.

The Atlas consists of sixteen plates. Each contains the record of about one month for one quarter of the length of spectrum from λ3600 to λ6600. The dispersion is prismatic: 0.7 A/mm at λ3600; 2.0 A/mm at Hγ; and 8.3 A/mm at λ6600. The time interval covered extends from discovery, December 13, 1934, to the deep minimum, April 25, 1935. The attempt was made to reproduce one spec-

trum for every twenty-four hour interval between those dates. Only a few strips are lacking,—chiefly in April when the nova was very faint. No identifications of lines are given, but the iron arc spectrum is reproduced at the top and bottom of each plate, with a scale of wave-lengths. A short text accompanies the Atlas and gives a history of the undertaking and points out some of the salient features.

One result of reducing to a common scale many spectra of originally very different dispersion is that the artistic qualities of a few plates are marred by strips which are so enlarged that the spectral details are lost in the grain pattern. But art had to be sacrificed to completeness of the scientific record. The over-enlarged spectra need only be viewed from a distance of several feet to appreciate the reason for including them, for they record at least the presence or absence of certain major features. And in each case the grainy strip represents the best available photograph for the date concerned. Some apparent variations of intensity or sharpness of lines are due to differences of contrast or to occasional poor focus on the original spectrograms. An exception should be noted: the ill-defined appearance on December 25 is real, and is due to the simultaneous presence of two sets of absorption lines, which can be seen resolved in the region of higher dispersion.

Critical examination shows that there has certainly been a minimum of loss of detail in reproduction. Extremely fine and weak lines of the principal absorption spectrum are recorded to a late date, and first traces of diffuse Orion lines are discernible at as early a date as on original spectrograms. The gradual emergence of the "diffuse enhanced" spectrum early in January can be traced from day to day at many lines, and its later multiplicity at the hydrogen lines is brought out clearly. In March the Atlas shows rapid changes of intensity of the Orion absorption lines. The fading of the continuous spectrum and the disappearance of the absorption came very suddenly and are well shown.

One of the greatest values of the Atlas is the opportunity it affords each observer of the nova to correlate his material with the whole. Many details in the gaps in each observatory's series of spectrograms can probably be cleared up by study of the Atlas. The value of the work is also permanent; it will furnish to students of novae many years hence a record of the changes which could probably never be reassembled. The authors are to be congratulated on the success of their undertaking and on the beauty of the finished prdouct.

DEAN B. MCLAUGHLIN.

Trigonometrical Tables, prepared by H. M. Nautical Almanac Office.

This collection of tables is different from the usual tables in that the argument is given in time. It is quite detailed as there is an entry for every second from 0^h to 3^h. The natural values of the sine, tangent, cotangent, and cosine functions are given to seven places of decimals. These features were all incorporated for the purpose of making the tables most serviceable to the astronomer. The natural functions also lend themselves to computations by machines which are now so generally in use. An auxiliary table containing the values of $x^s \cos x^s$ for all values of x from 0 to 1800 is included. These tables will fill a useful purpose, especially in work in positional astronomy.

Indicative of the times is the fact that the address of H. M. Nautical Almanac Office, given in connection with this publication, is Code 9, Town AA, England. Further interest to us arises in that our card of acknowledgment of the volume, sent to the given address, was returned to us, bearing evidence that it had been in London, marked "Insufficiently addressed." This item, although not a part of the

review, is incorporated in it, so that if the review should come to the notice of the authorities concerned, the fact that they did not receive an acknowledgment from us will be explained.

C. H. GINGRICH, *Editor.*

The Observer's Handbook for 1940.—The edition of this publication of eighty pages for the year 1940 is the thirty-second in the series. It is published by The Royal Society of Canada at 198 College Street, Toronto, under the editorship of Professor C. A. Chant and Dr. F. S. Hogg, of the David Dunlap Observatory. Its contents are grouped in twenty-eight sections, all pertaining to astronomical phenomena or events depending upon them. Typical among the items are The Constellations, Ephemeris of the Sun, Lunar Occultations, Variable Stars. The student who might be puzzled by the astronomical data published in the elaborate year books by a number of the countries will find the facts here in a quite accessible form. It will serve a useful purpose also in any observatory in which astronomical observations are regularly being made.

Scientific Riddles, by Professor Sir J. Arthur Thomson. (The Scientific Book Club, 121 Charing Cross Road, London, W.C. 2. Price 2/6.)

This book was the choice of the Scientific Book Club (London) for August, 1938. This mention of the volume is, therefore, somewhat delayed. However, it is still timely because the Riddles referred to in the volume have been unsolved for many years and still continue to be so. That, indeed, is the fascination of this volume.

It is divided into four parts having twenty-five, fourteen, six, and seven items, respectively, a total of fifty-two. As typical of the Riddles, the following titles may be mentioned: How did Life begin?, Are Animals ever afraid?, Why must We die?, How is the Earth kept so clean?, Is there a Natural "Wireless"?, Is Telepathy a Fact?, Is there Cruelty in Nature?.

The reviewer does not feel entirely satisfied with the above selection, for each of the fifty-two titles might equally well have been included. Not only are these questions raised, but illuminating and exceedingly intelligent discussion of them is presented in the 378 pages by the well-known and authentic author. Even though the final answer is not given, the setting of and the pertinent facts related to the riddles, or seeming paradoxes, are clearly brought out.

A large proportion of the literate has recently become science conscious. In this volume one may come close to many questions, which are fundamentally scientific, without delving into the usually forbidding and deterring technicalities.

Planetary Coördinates for the Years 1940-1960, Prepared by H. M. Nautical Almanac Office, London. Price 17 s. 6 d. net.

This forward-looking, octavo-sized, well-printed, and neatly-bound volume of one hundred fifty pages bears the imprinting date, January, 1939. It is in continuation of a similar volume issued in 1933 which pertained to the period 1800 to 1940. From the preface we learn that "Although the present volume was originally planned to cover the years 1940 to 1960, the opportunity has been taken to include the spherical coördinates of Uranus and Neptune from 1800 to 1903 (from which date onwards the first volume provides the coördinates) at an interval of 200 days; for this purpose, they were specially computed from Newcomb's tables. The two volumes together thus include all the basic planetary data likely to be required in

the computation of planetary perturbations from 1800 to 1960." In the event that the earlier volume may not be available to all users of this one, all the necessary auxiliary tables and explanation have been reprinted in this volume. We note also that it is the intention of the same office to issue a continuation to this volume before the period for which this one is applicable has expired.

This series, therefore, is a good example of the coöperation and helpful service rendered by scientists of one nation to scientists of all other nations,—a situation conspicuously different from that in some other aspects of international relationships at present.

Tables for Converting Rectangular to Polar Coördinates, by J. C. P. Miller. (Scientific Computing Service, Limited, 23 Bedford Square, London. Price, two shillings.)

This compilation of tables is a pamphlet of 16 pages arranged in a very ingenious manner to accomplish the purpose indicated. With skillful use of signs and ratios and simple properties of the trigonometric functions a large range of values is included in a surprisingly small space. While such tables may be needed relatively infrequently, when they are needed they will save much laborious computation. A supplementary table for reducing angles to the first quadrant with detailed instruction for using it is found on page 16.

The tables are bound in flexible fabricoid of durable quality and consequently will furnish long and hard use.

THE HORSE-HEAD NEBULA

Ah, to softly slip behind the scene
One clear and snow-draped, silent winter night,
To pierce the density which seems to screen,
Obstruct the splendor of that cosmic light,
To pass beyond that dark and mystic cloud
Which looms like portal in a garden wall,
The ancient loveliness within to shroud,—
How it one's fancy does inspire, enthrall.
In that great starlit garden of the sky,
Where light eternal dwells in calm repose,
Who knows what beauty there might greet the eye,
What undreamed truth a brief glimpse there disclose
As strange as thought, to thought there is no space,
At will, one's thoughts the universe may embrace.

—Lisa Odland.

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